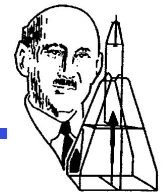
# Sciences and Exploration Directorate

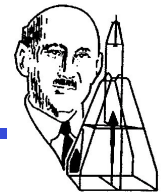


The Sciences and Exploration Directorate at GSFC provides scientific *leadership* and *stewardship* to *enable* space-based research studies of the Earth, the Sun-Earth interaction, the Solar System and the Universe

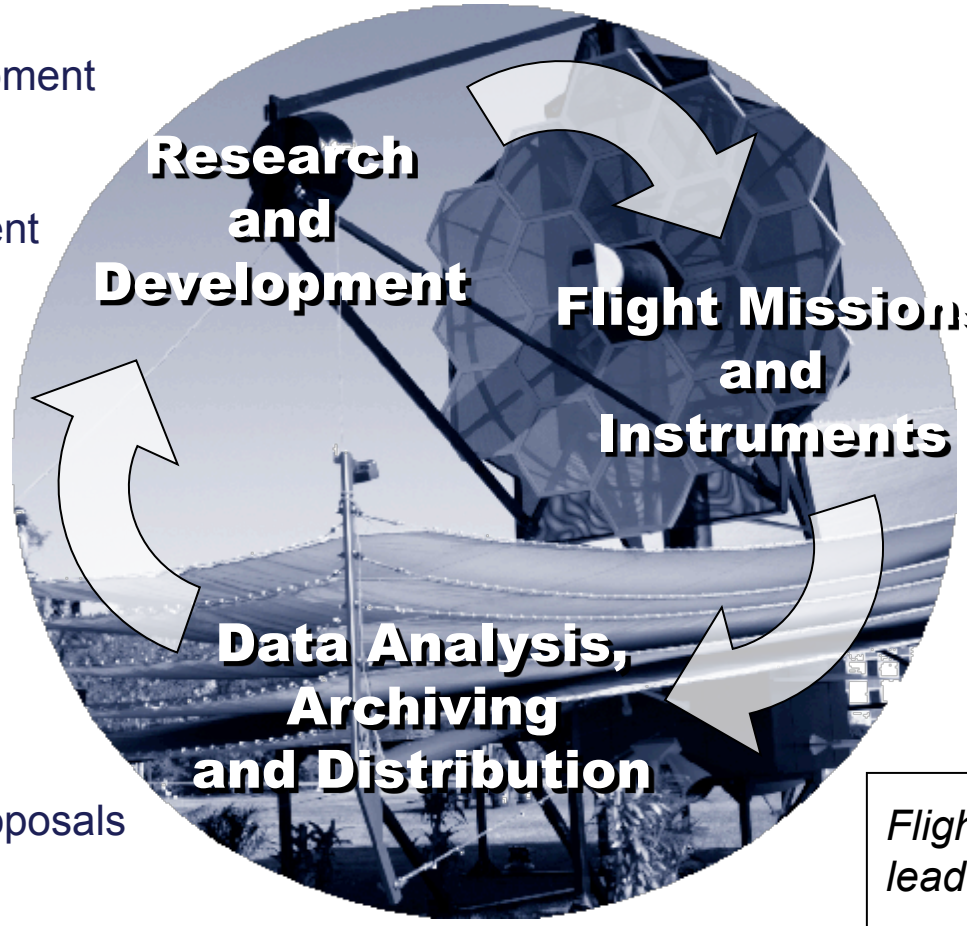
- Project Scientists who ensure that mission scientific goals are defined and realized, and are the project interface to the science community
- Research projects that are beyond the scope of universities, supported by small-scale, cutting-edge efforts to keep the workforce sharp
- Data modeling and science data centers to realize and maintain the scientific return of missions
- Education and Public Outreach to widely communicate and NASA's science program and inspire the next generation of scientists

SED: Excellence, Stewardship, Vision

# GSFC Supports the Entire Mission Life Cycle



- Lab experiments
- Technology Development
- Theory / Modeling
- Field Studies
- Concept Development




*SED usually lead in these two areas*

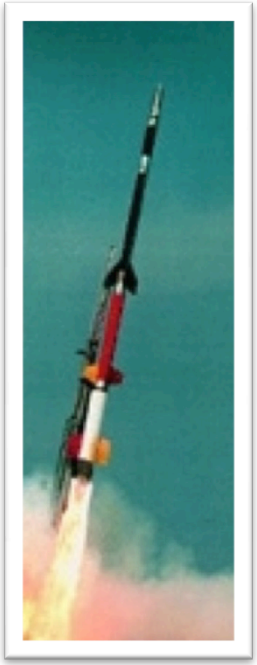
- Project Management
- Engineering
- Fabrication, Integration & Test
- Mission Design & Development
- Launch & Operations

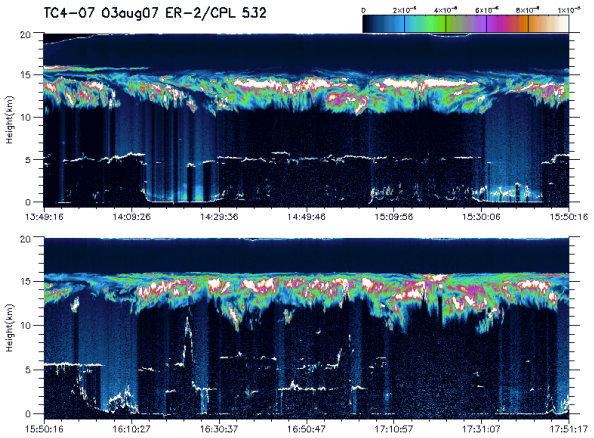
*Flight Programs usually lead in this area*

- Observation Proposals
- Data Archives
- Applications
- Long-Term Modeling
- Data Products

# Sub-orbital & Aircraft Research Programs

## Aircraft, Balloon & sounding Rocket Programs provide Important research, training experience, demonstration of instrumentation, as well as excellent science








SED: Excellence, Stewardship, Vision

# GSFC Data Archives and Modeling

SED/600 provides many different data and modeling services to the world-wide science community

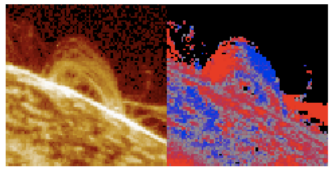
HEASARC

National Space Science Data Center

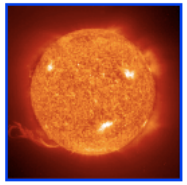
NASA Goddard Space Flight Center
GLOBAL MODELING AND ASSIMILATION OFFICE

Community Coordinated Modeling Center

GES DISC
Goddard Earth Sciences Data and Information Services Center
Your source for earth science data and information

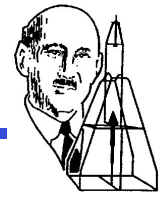


SDAC



Welcome to the **Solar Data Analysis Center** at NASA Goddard Space Flight Center in Greenbelt, Maryland USA.

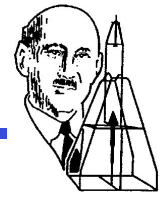
# Setting the Priority of Science



- Strategic missions usually are >$1B and are prioritized by the National Academy of Sciences every ten years through a Decadal Survey process, that engages the entire community to reach a consensus as to the highest priority
- Smaller, more directed science missions are typically competed via announcements of opportunity and are cost capped e.g. Explorers, Discovery, New Frontiers, Venture Class

GSFC partners with scientists at universities and other government labs to undertake these missions – we must be customer orientated!

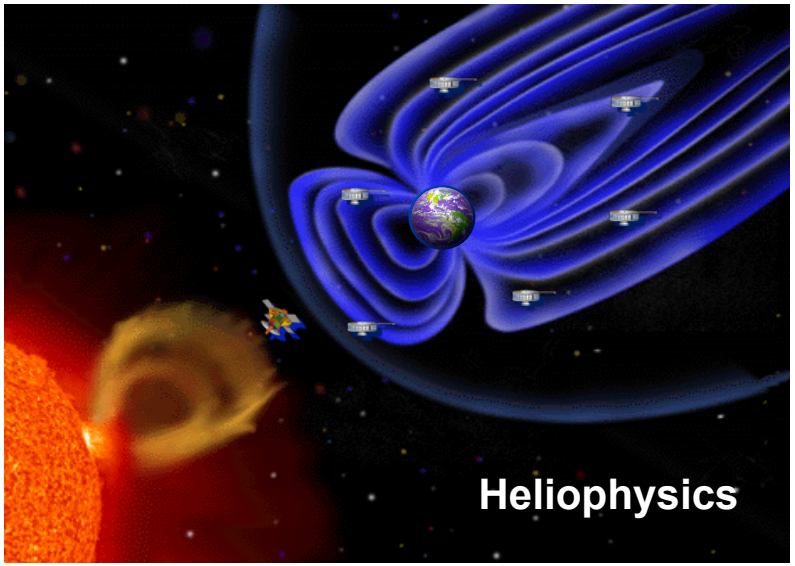
# Funding of Research at NASA



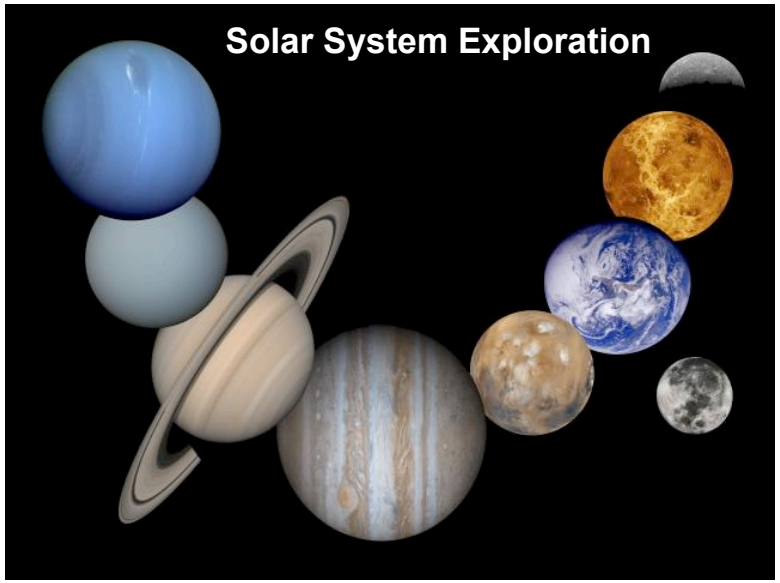
- GSFC science research is driven by community peer review in a full and open competition
- NASA scientists must write proposals and compete with the external science community for research funds (including their salaries)
- There is also internal competition for center IRAD funds, as well as B&P to support proposal efforts
- Directed work is only related to project science and other service activities (equivalent to teaching at a University)

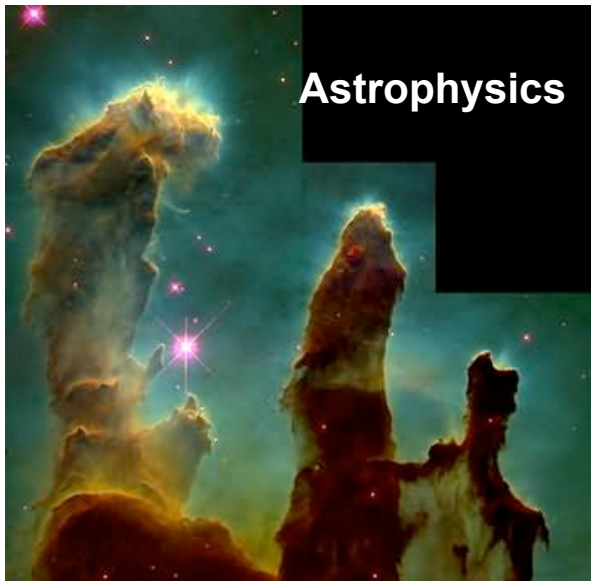
***There is a lot of proposal writing in code 600!***

# Sciences and Exploration Divisions







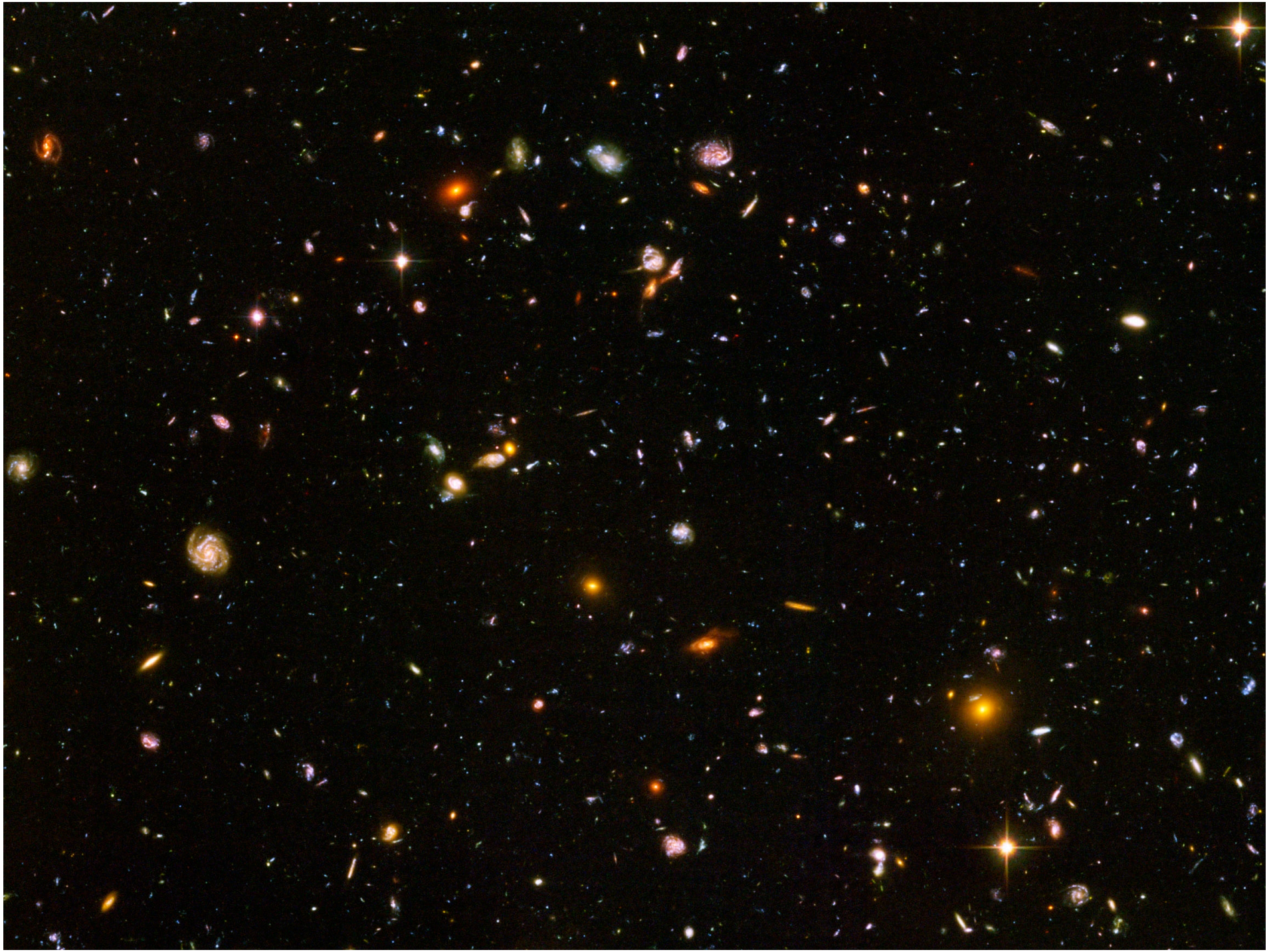





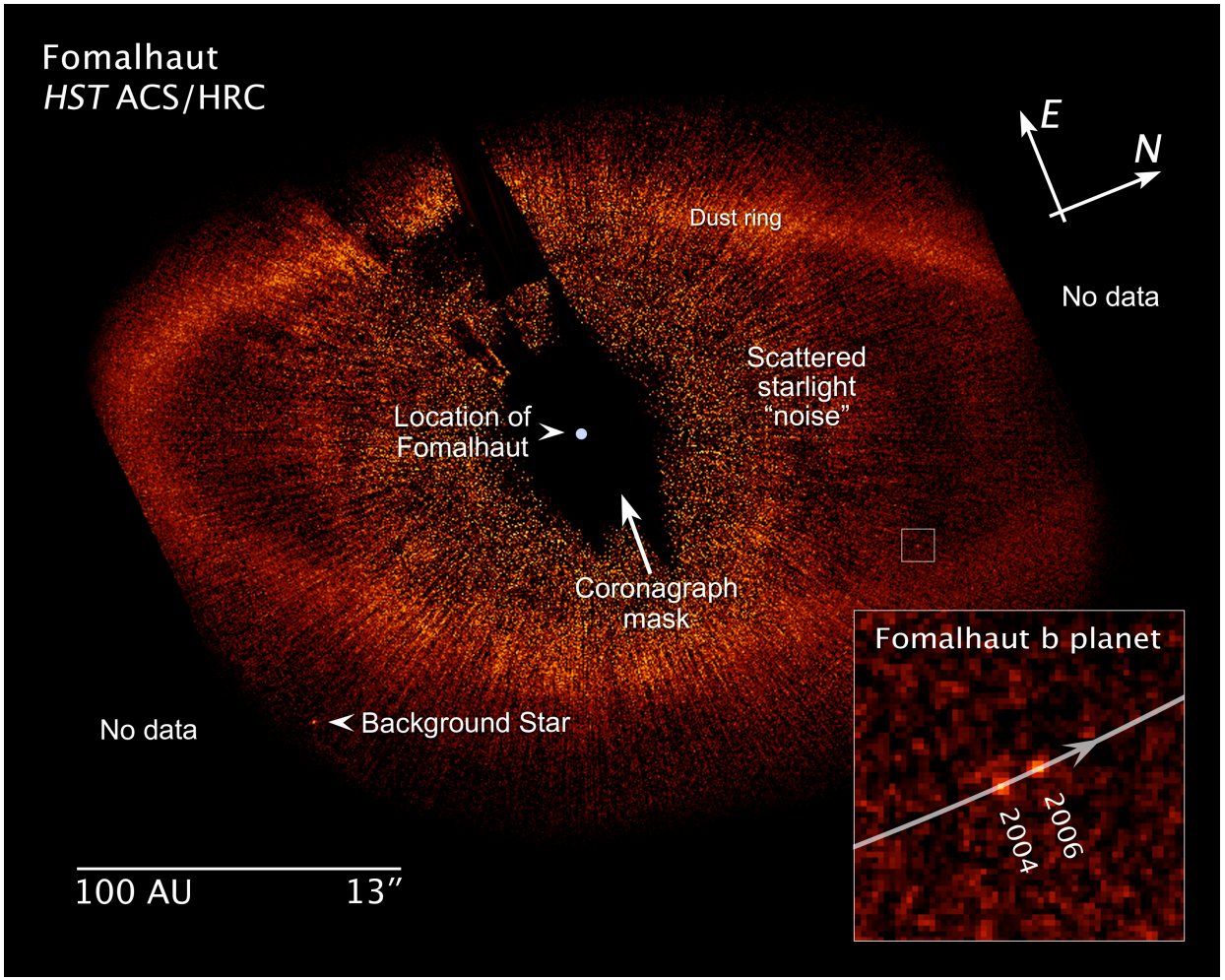

SED: Excellence, Stewardship, Vision

# Astrophysics

M101 Pinwheel Galaxy from HST



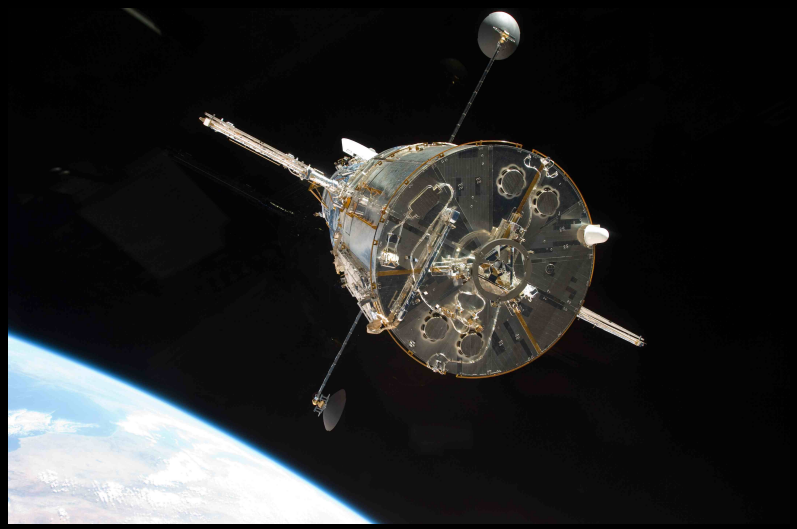
# First Direct detection of a planet



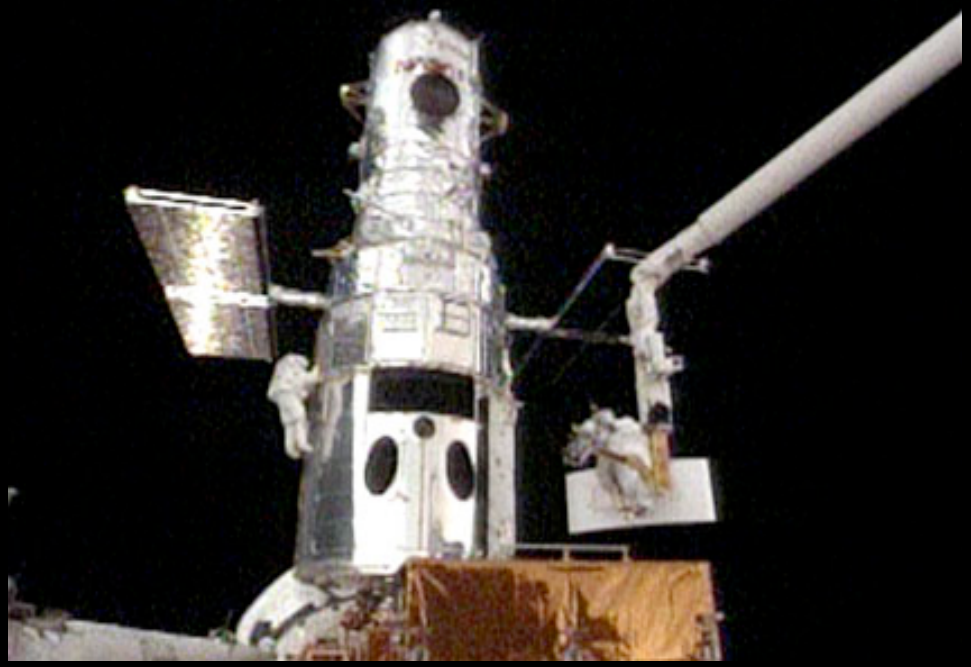

This visible-light image from HST shows the newly discovered planet, Fomalhaut b, orbiting its parent star – Mark Clampin (667)

# Hubble Space Telescope: Servicing Mission 4

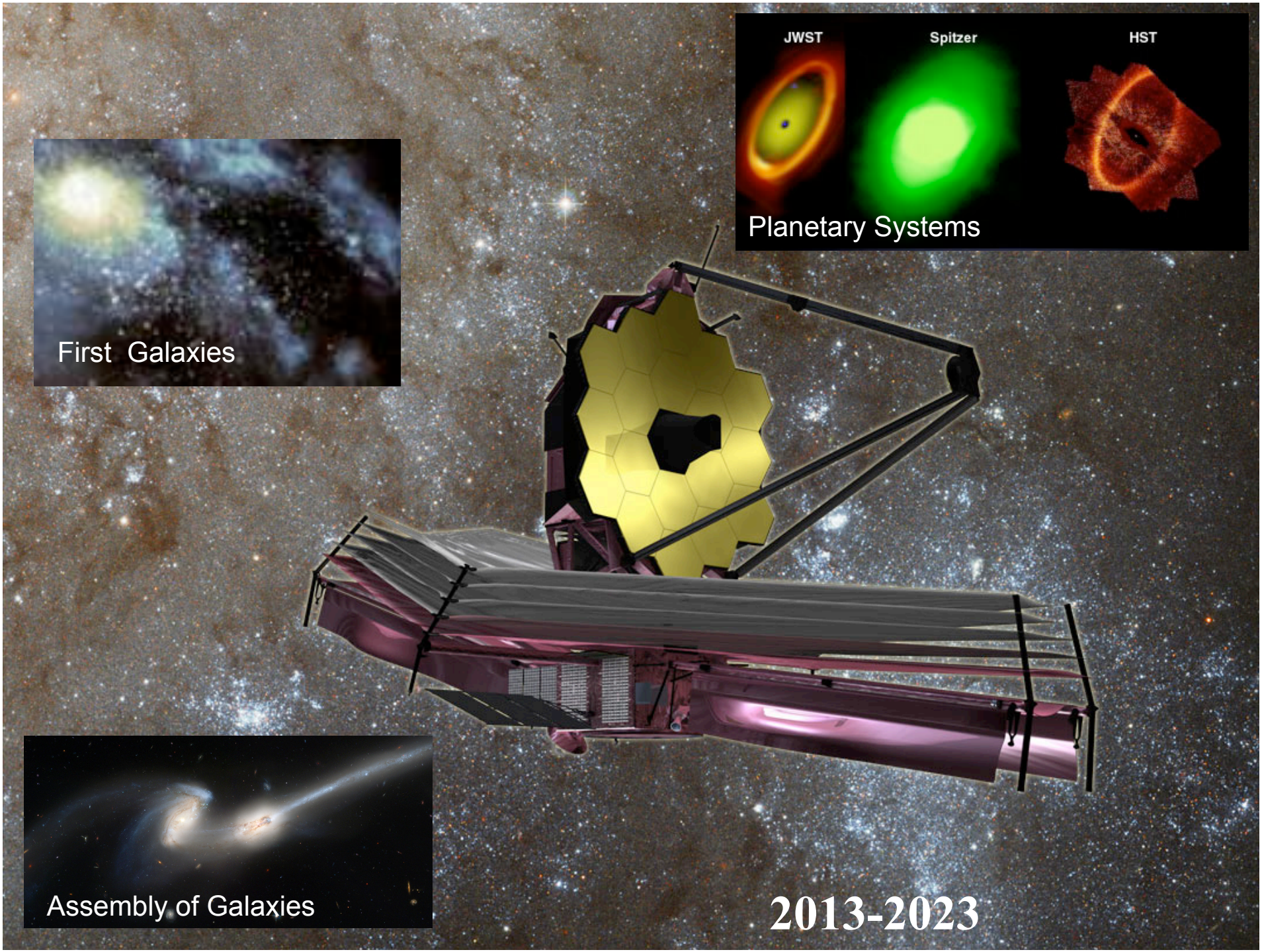
**SI&DH+Batteries+Gyros +FGS = Sustained HST Lifetime**



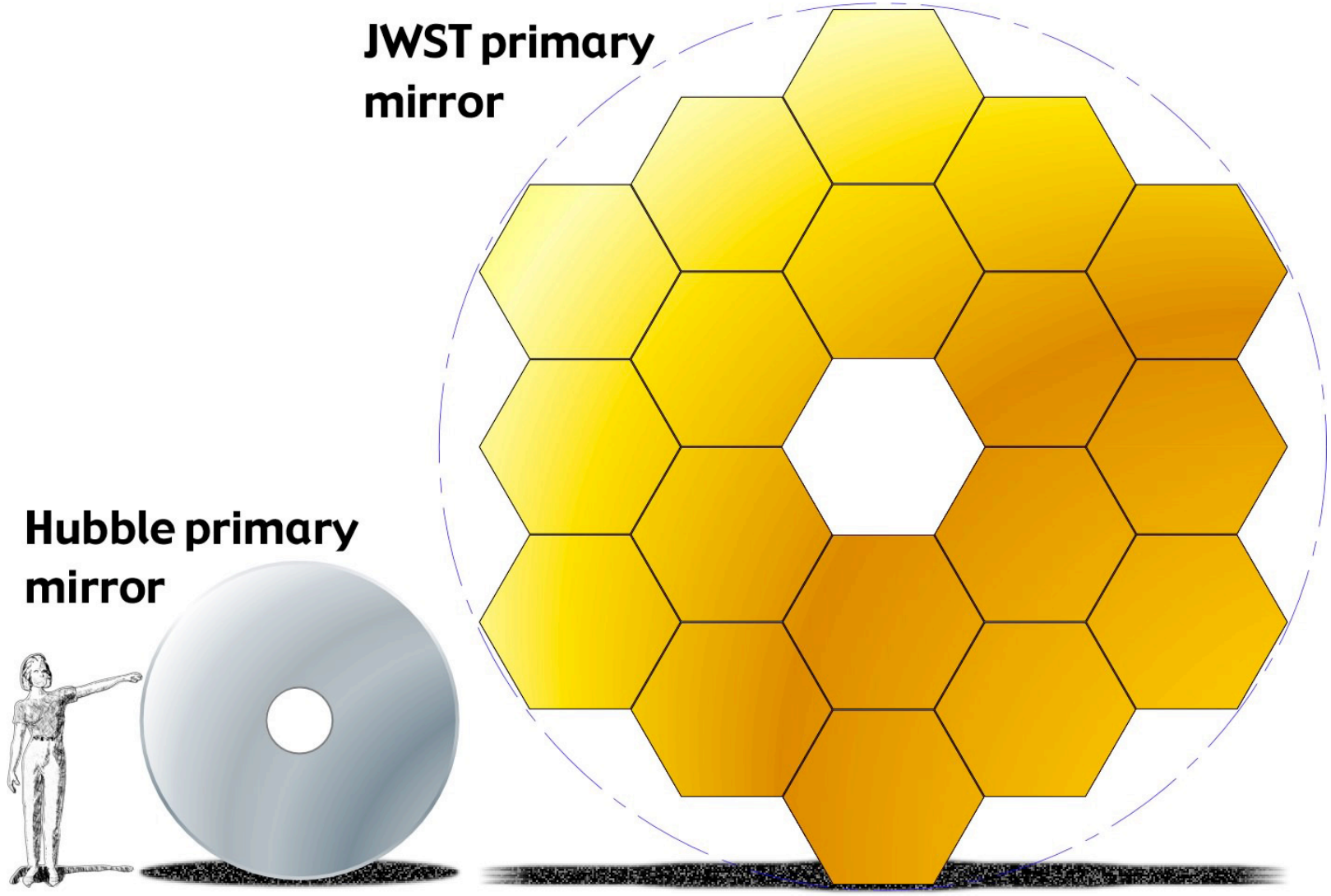
**Full set of spectroscopy tools for astrophysics (COS and repaired STIS)**



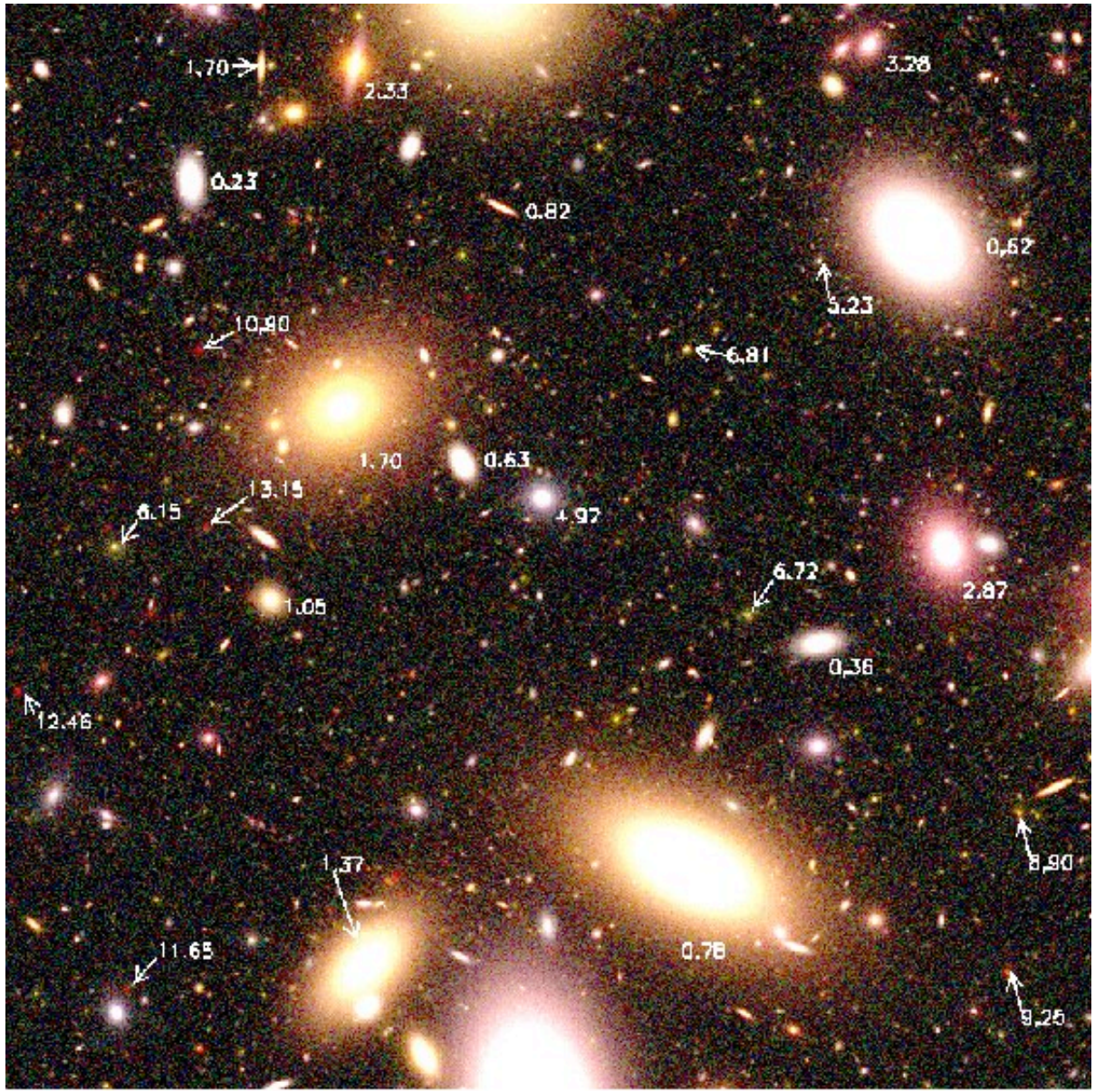
**Most powerful imaging ever (WFC3 and repaired ACS)**


JWST
Spitzer
HST
Planetary Systems
First Galaxies
Assembly of Galaxies
2013-2023

# Mirror size: JWST compared to HST



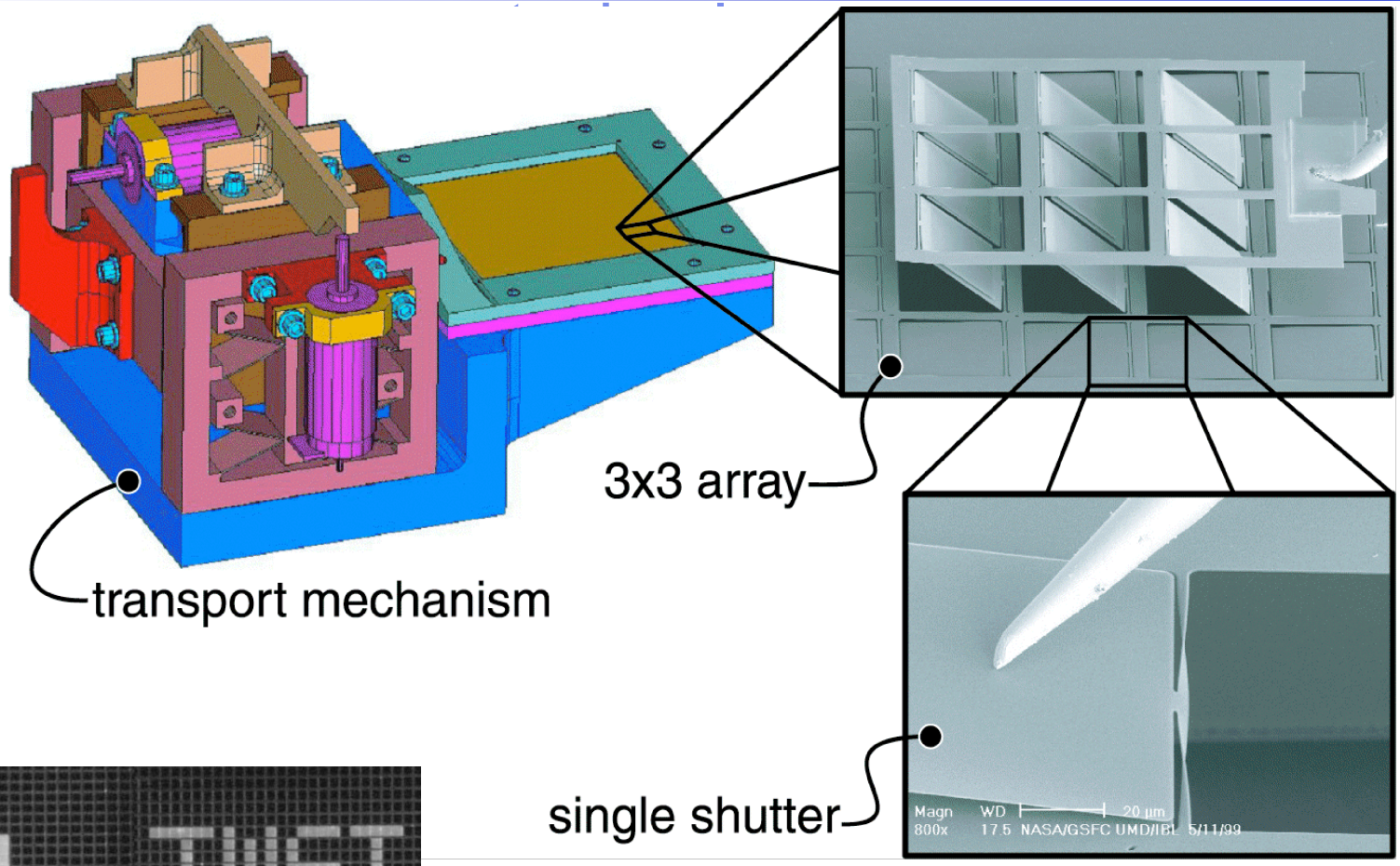
# JWST Deep Field

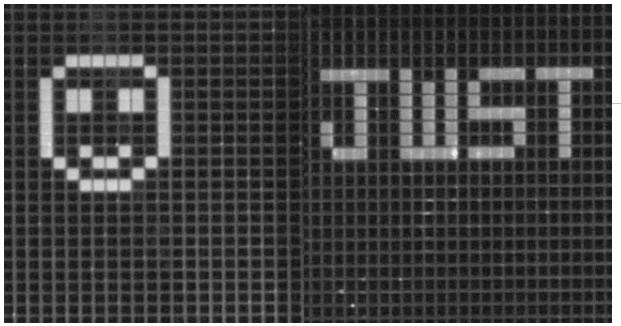





SED: Excellence, Stewardship, Vision

# JWST Micro-shutters – GSFC enabling



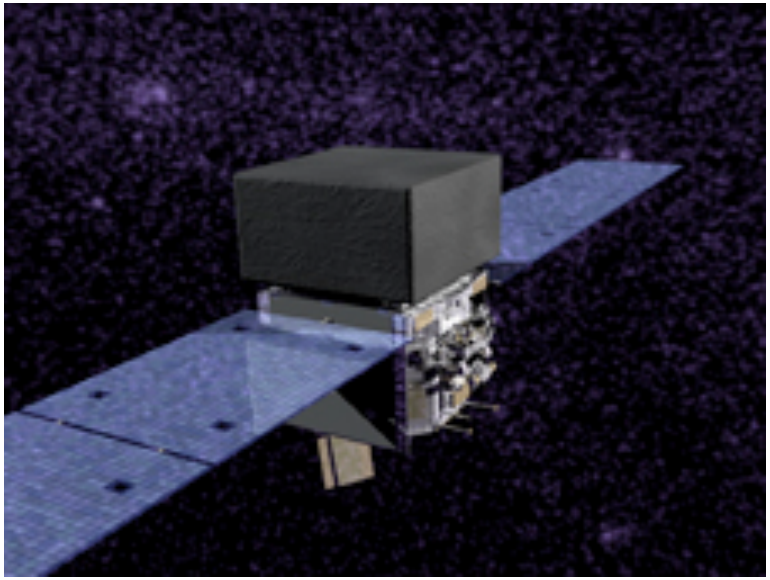
Harvey Moseley - 600
Murzy Jhabvala - 500

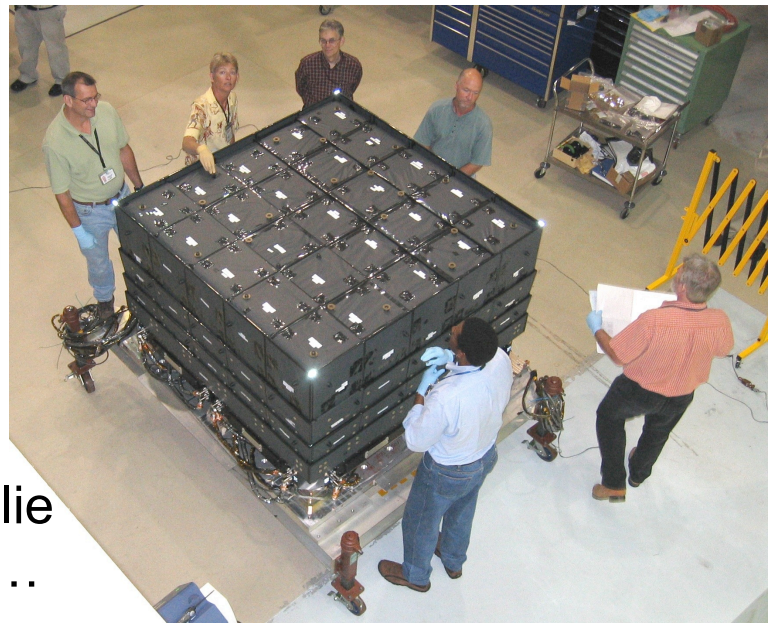


SED: Excellence, Stewardship, Vision

# Fermi Space Telescope (aka GLAST)

*Fermi is a joint NASA-Department of Energy program, with a large international collaboration*

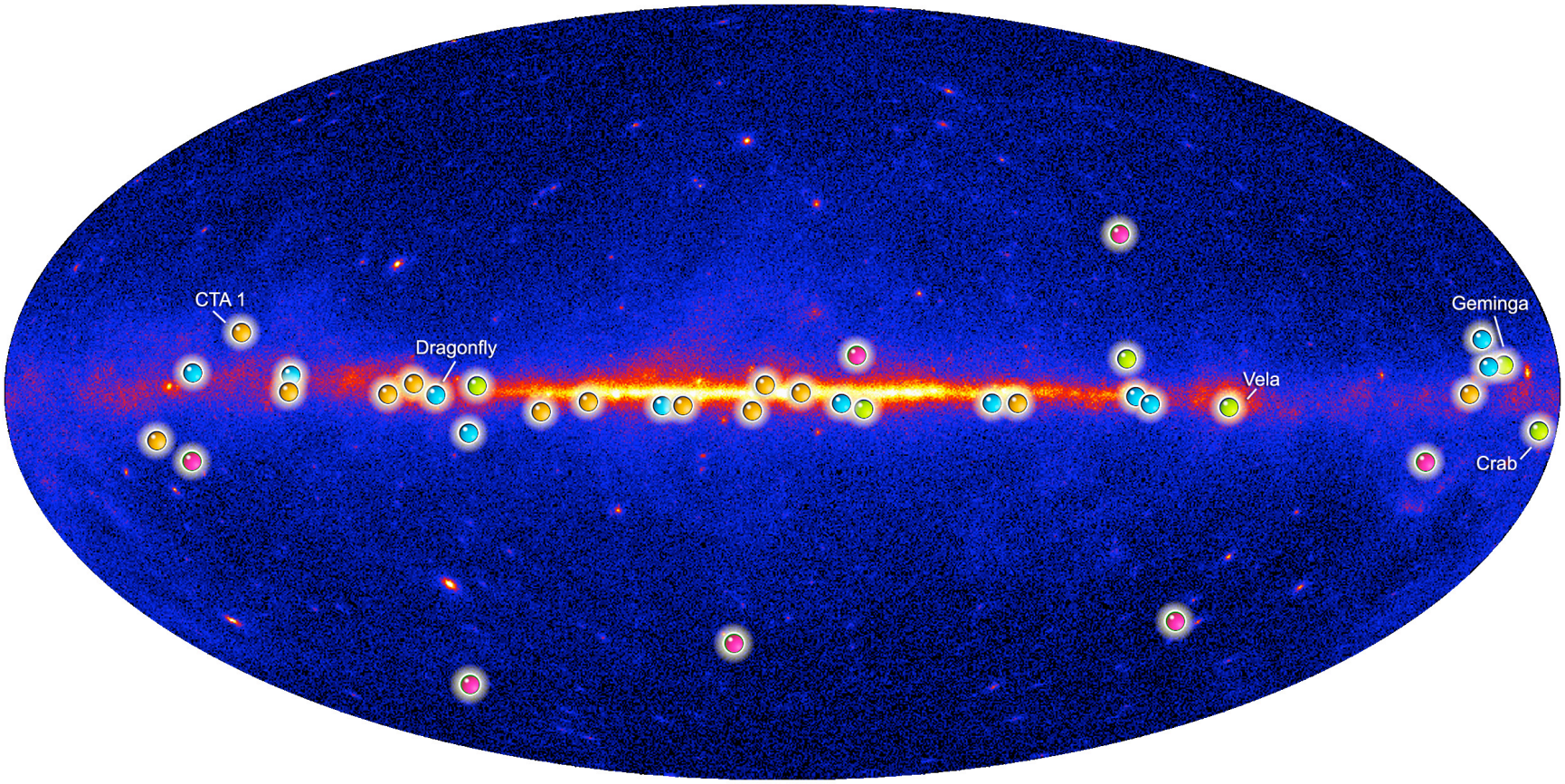




GSFC science leadership: Steve Ritz, Julie McEnry, Dave Thompson, Neil Gehrels, …

SED: Excellence, Stewardship, Vision

# Fermi discovers new class of Gamma-ray only pulsars



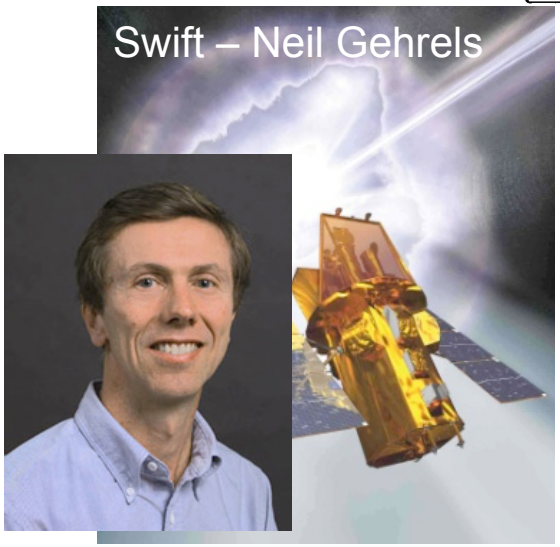

Fermi Pulsar Detections

- New pulsars discovered in a blind search
- Millisecond radio pulsars
- Young radio pulsars
- Pulsars seen by Compton Observatory EGRET instrument

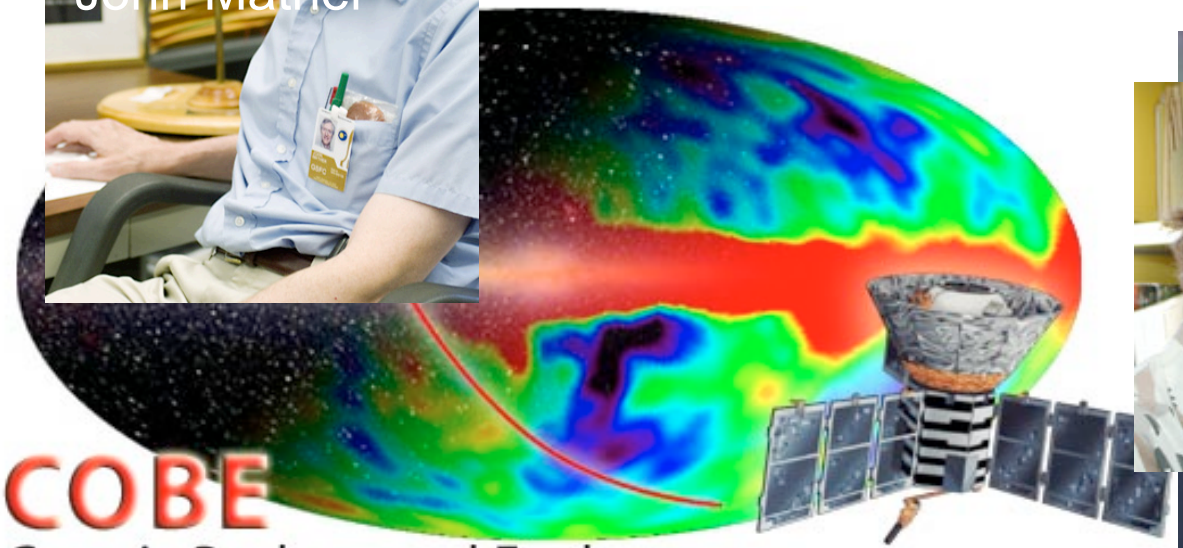
# GSFC Science Leadership of Astrophysics Missions

John Mather

WMAP – Chuck Bennett



Swift – Neil Gehrels



COBE
Cosmic Background Explorer

RXTE – Jean Swank

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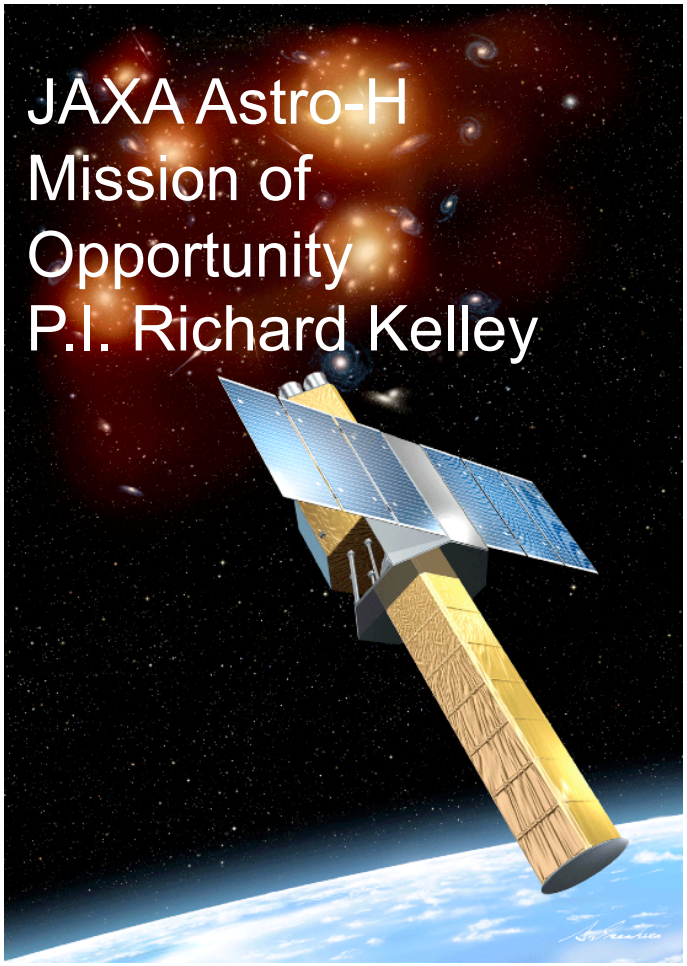
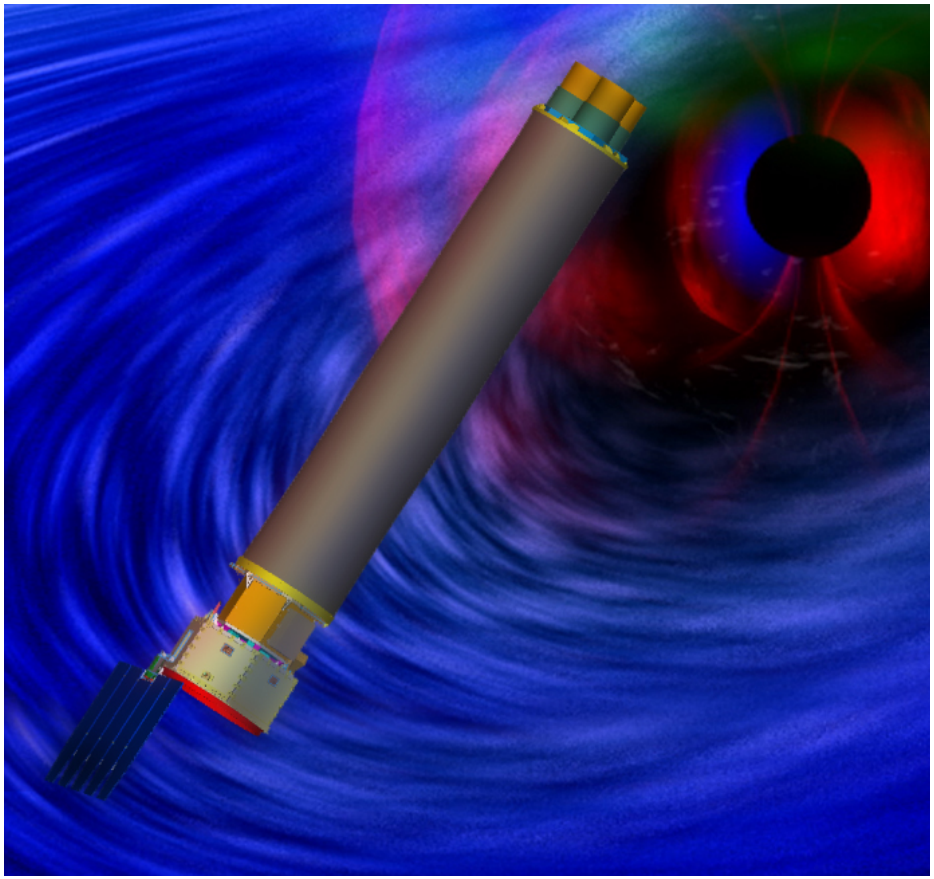
# GSFC SMEX Success



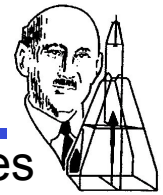

GSFC X-ray spectrometer

Gravity and Extreme Magnetism SMEX
P.I. Jean Swank

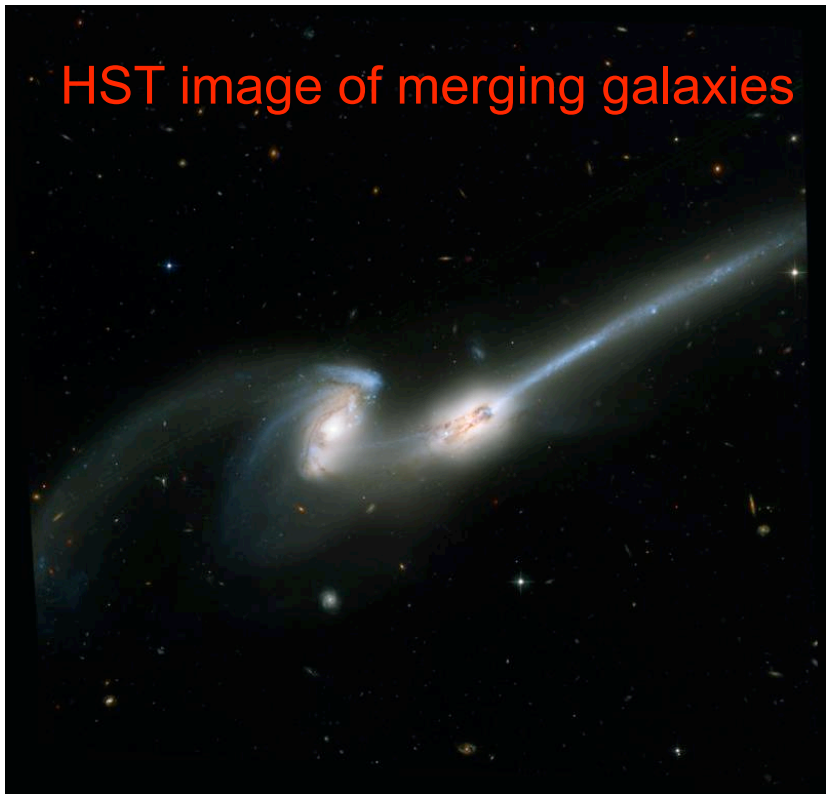


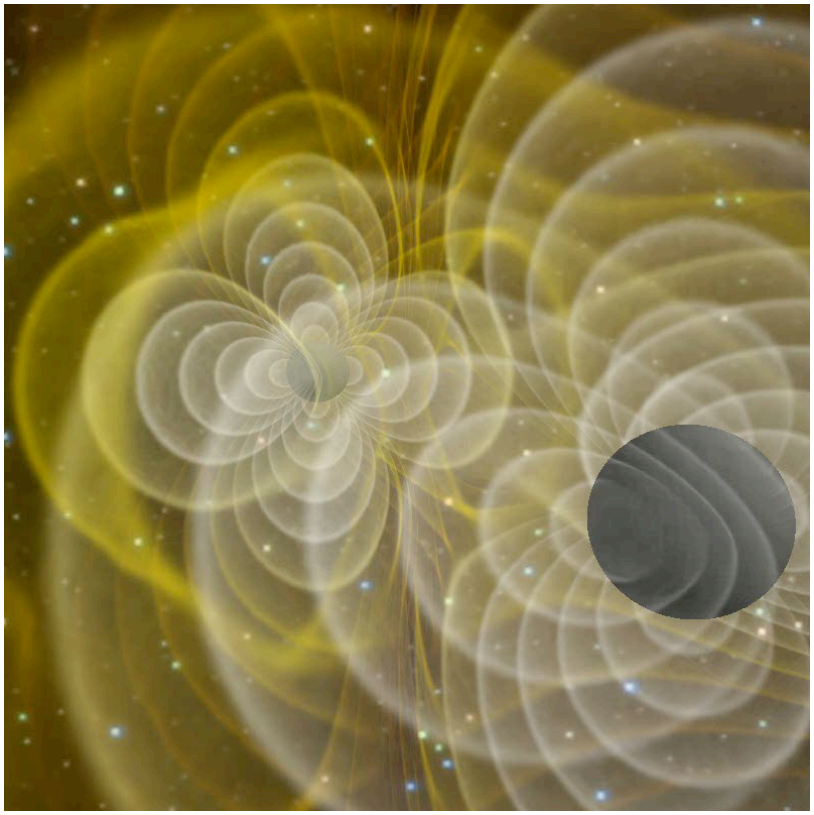
SED: Excellence, Stewardship, Vision

# Gravitational Wave Astronomy



Simulation of merging Black Holes



Joan Centrella and John Baker undertake ground breaking work in modeling the merger of black holes and the resulting gravitational wave signals relevant to the future LISA mission

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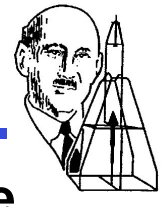
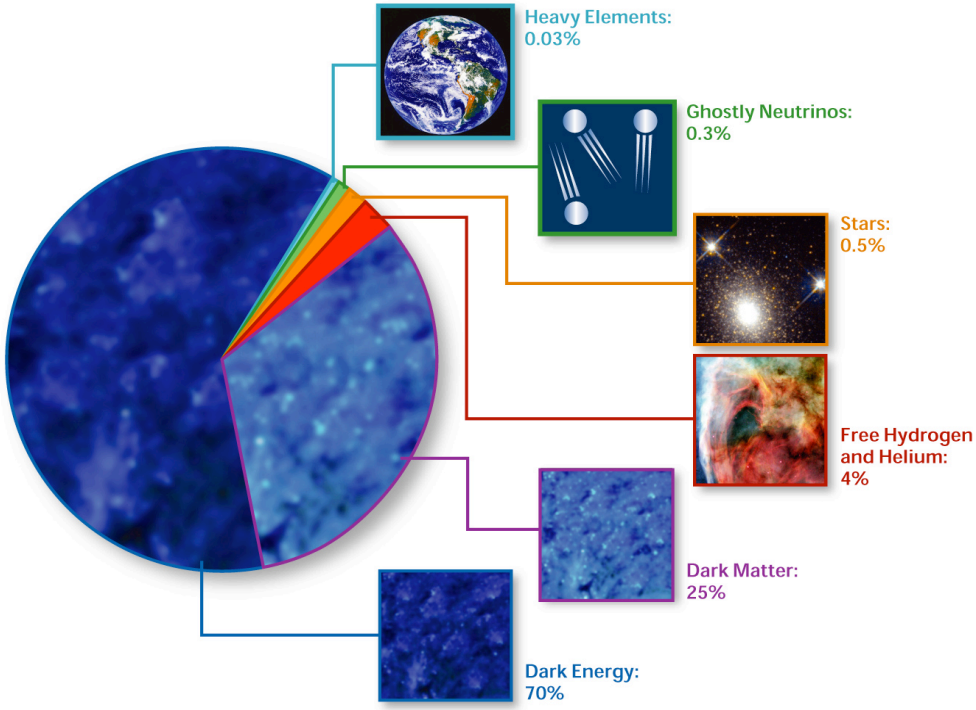
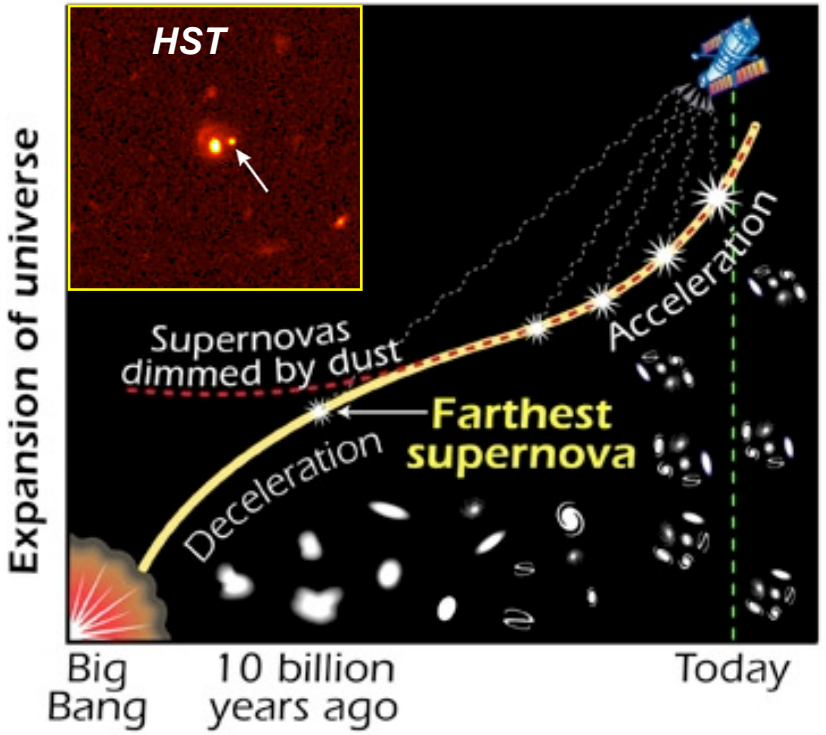
# Exploring the Dark Side of the Universe



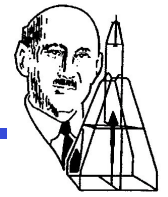
**A mysterious Dark Energy, that makes up 70% of the Universe is causing the expansion of the Universe to accelerate**



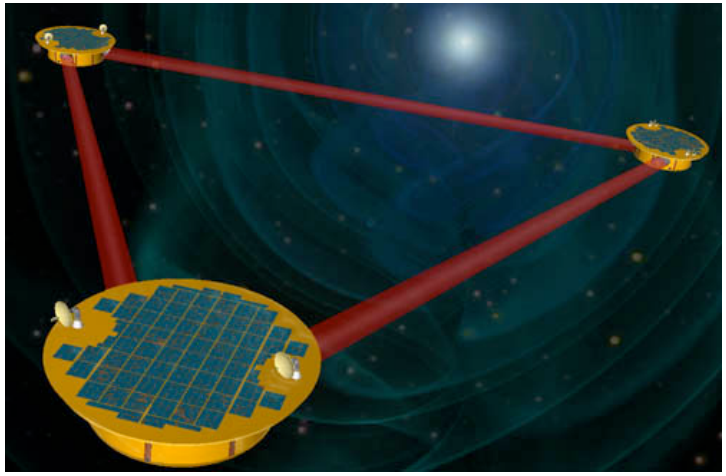




**GSFC will manage and build major parts of the Joint Dark Energy Mission (JDEM)**

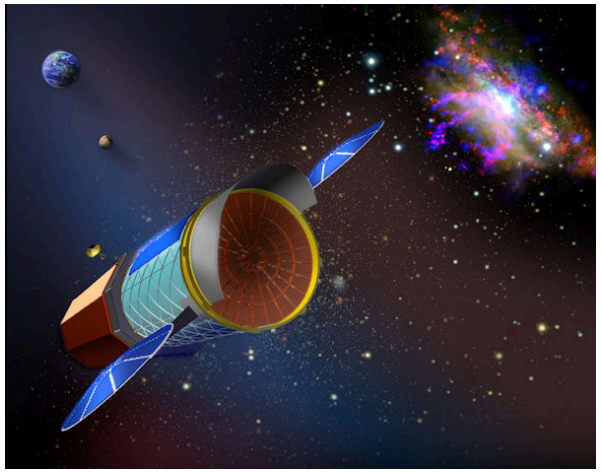
# Astrophysics Future – Decadal Survey



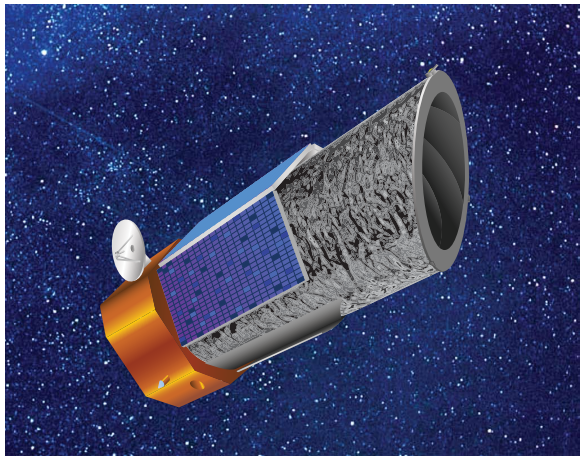
## Some candidate missions



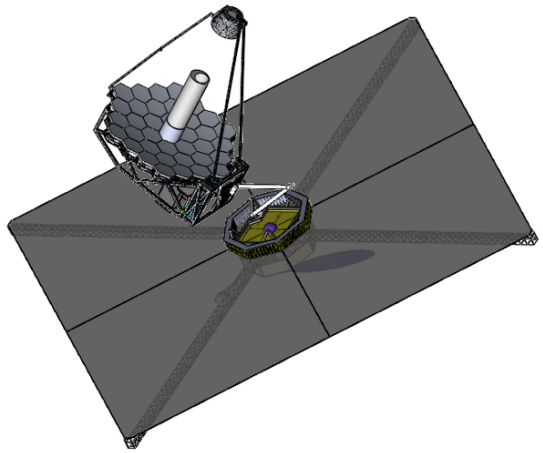
Laser Interferometer Space Antennae - LISA



International X-ray Observatory - IXO



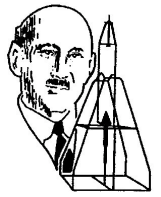
Joint Dark Energy Mission - JDEM



ATLAST/ST2020

SED: Excellence, Stewardship, Vision

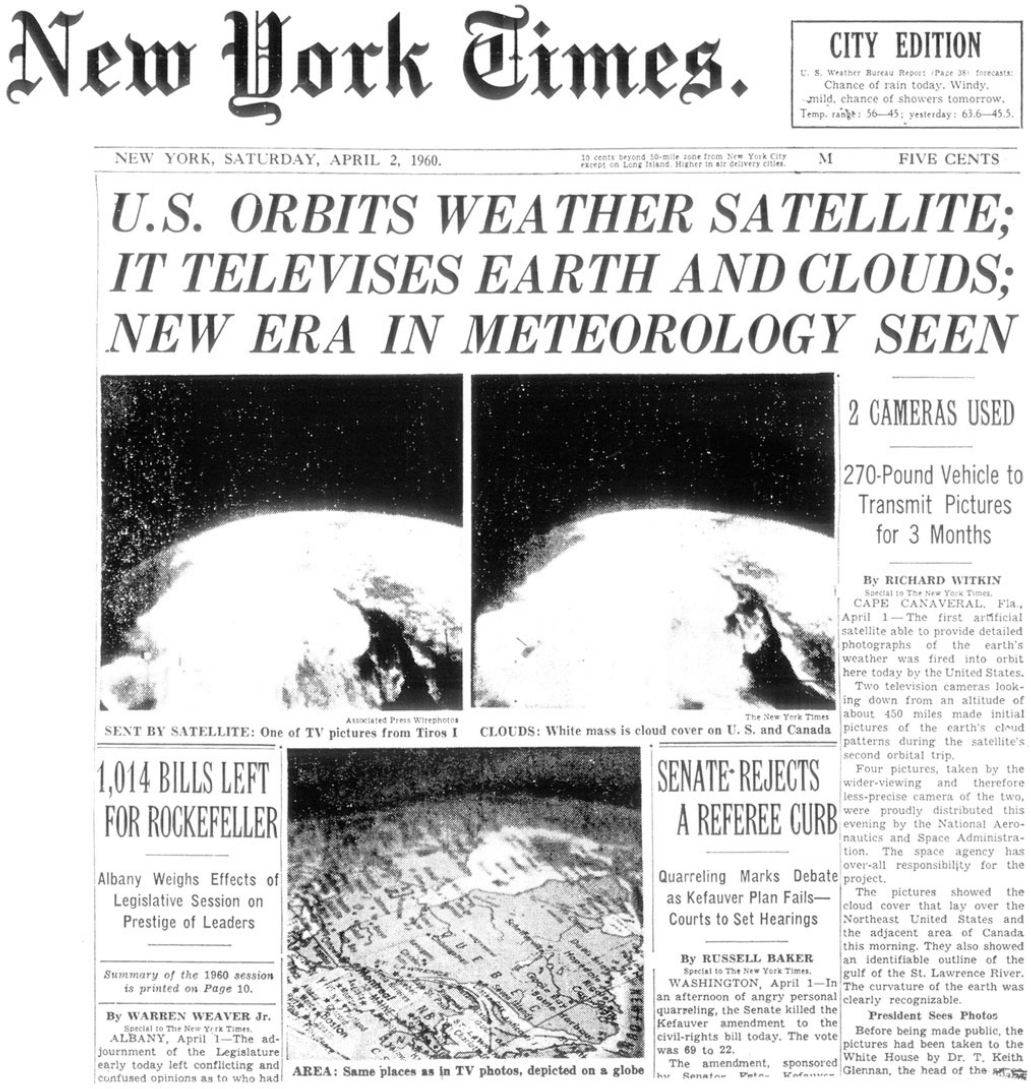
# A Proud GSFC Earth Science History



***TIROS I***

***GSFC mission launched April 1, 1960***

***The first picture from space. Here is where NASA began its mission of observing the Earth's weather.***



New York Times.

CITY EDITION

U. S. Weather Bureau Report (Page 38): forecasts: Chance of rain today. Windy, mild, chance of showers tomorrow. Temp. range: 56—45; yesterday: 63.6—45.5.

NEW YORK, SATURDAY, APRIL 2, 1960. 10 cents beyond 50-mile zone from New York City except on Long Island. Higher in air delivery cities. M FIVE CENTS

U.S. ORBITS WEATHER SATELLITE; IT TELEVISES EARTH AND CLOUDS; NEW ERA IN METEOROLOGY SEEN

Associated Press Wirephotos

SENT BY SATELLITE: One of TV pictures from Tiros I

The New York Times

CLOUDS: White mass is cloud cover on U. S. and Canada

2 CAMERAS USED

270-Pound Vehicle to Transmit Pictures for 3 Months

By RICHARD WITKIN

Special to The New York Times.

CAPE CANAVERAL, Fla., April 1—The first artificial satellite able to provide detailed photographs of the earth's weather was fired into orbit here today by the United States.

Two television cameras looking down from an altitude of about 450 miles made initial pictures of the earth's cloud patterns during the satellite's second orbital trip.

Four pictures, taken by the wider-viewing and therefore less-precise camera of the two, were proudly distributed this evening by the National Aeronautics and Space Administration. The space agency has over-all responsibility for the project.

The pictures showed the cloud cover that lay over the Northeast United States and the adjacent area of Canada this morning. They also showed an identifiable outline of the gulf of the St. Lawrence River. The curvature of the earth was clearly recognizable.

President Sees Photos

Before being made public, the pictures had been taken to the White House by Dr. T. Keith Glennan, the head of the

1,014 BILLS LEFT FOR ROCKEFELLER

Albany Weighs Effects of Legislative Session on Prestige of Leaders

*Summary of the 1960 session is printed on Page 10.*

By WARREN WEAVER Jr.

Special to The New York Times.

ALBANY, April 1—The adjournment of the Legislature early today left conflicting and confused opinions as to who had

AREA: Same places as in TV photos, depicted on a globe

SENATE REJECTS A REFEREE CURB

Quarreling Marks Debate as Kefauver Plan Fails—Courts to Set Hearings

By RUSSELL BAKER

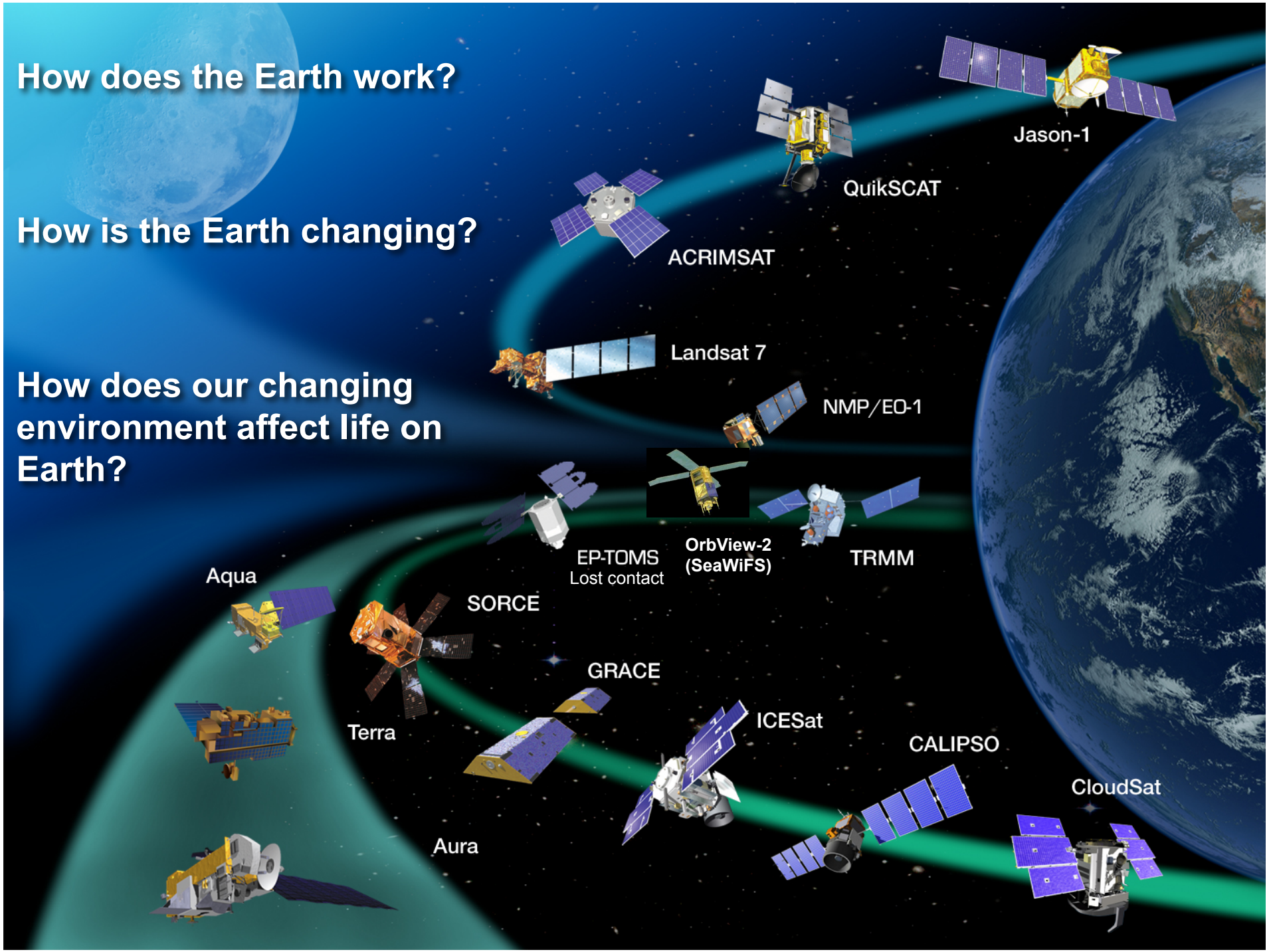
Special to The New York Times.

WASHINGTON, April 1—In an afternoon of angry personal quarreling, the Senate killed the Kefauver amendment to the civil-rights bill today. The vote was 69 to 22.

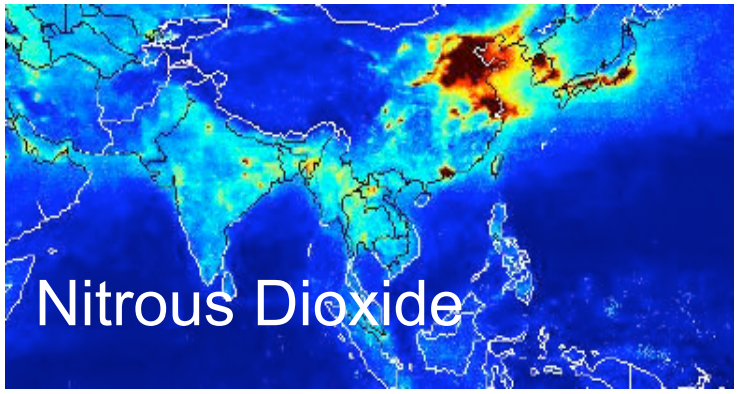
The amendment, sponsored

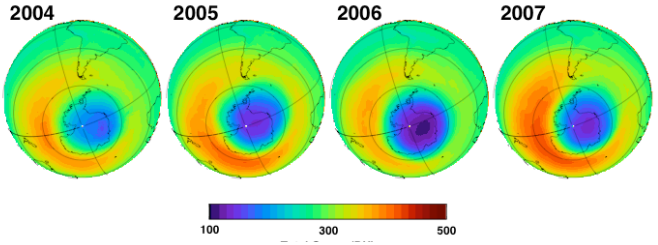


SED: Excellence, Stewardship, Vision

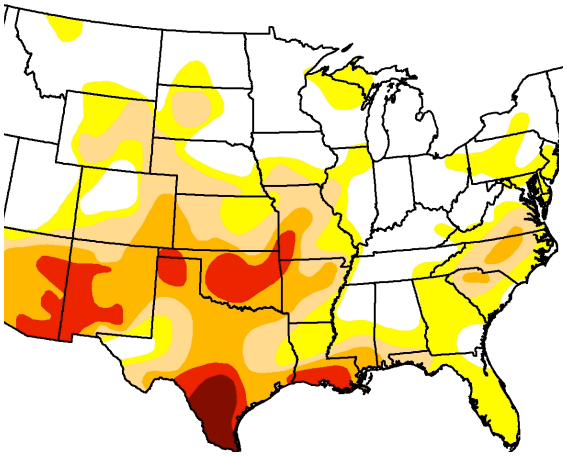

How does the Earth work?
How is the Earth changing?
How does our changing environment affect life on Earth?
Jason-1
QuikSCAT
ACRIMSAT
Landsat 7
NMP/EO-1
EP-TOMS
Lost contact
OrbView-2
(SeaWiFS)
TRMM
Aqua
SORCE
GRACE
Terra
ICESat
CALIPSO
CloudSat
Aura

# Multi-facetted Earth Science Research

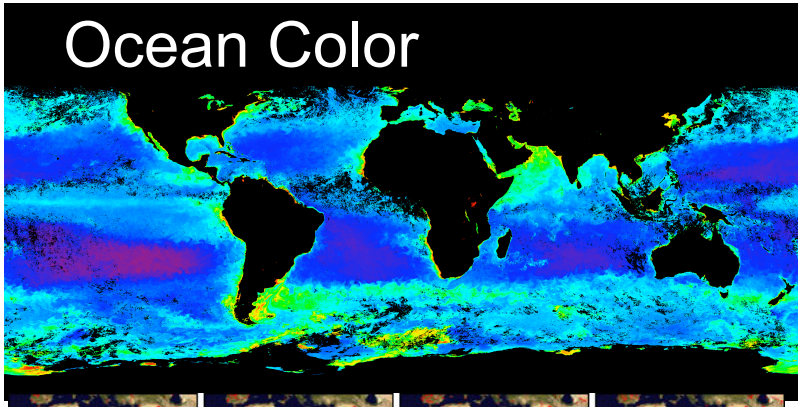


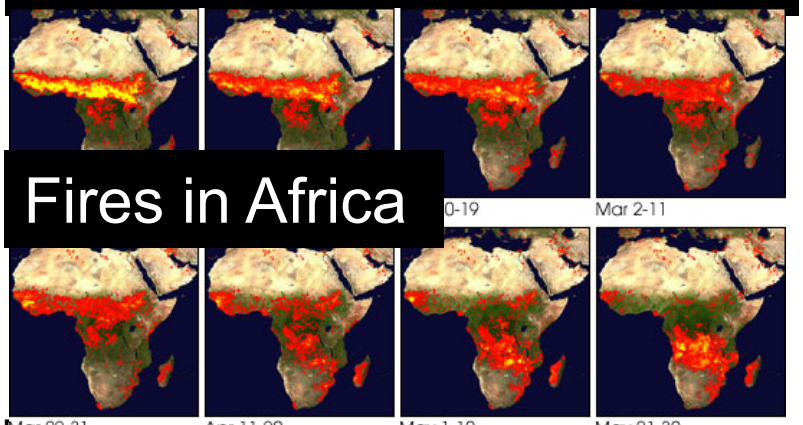




Ozone

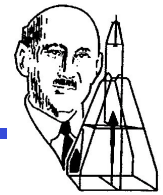


Ground Water



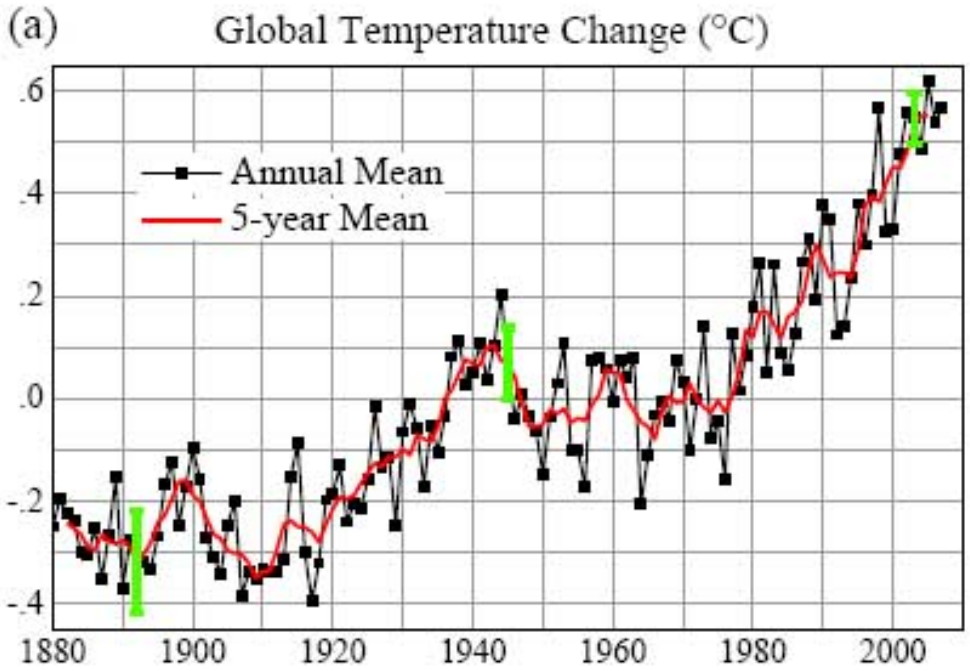

# What NASA has done for climate change studies



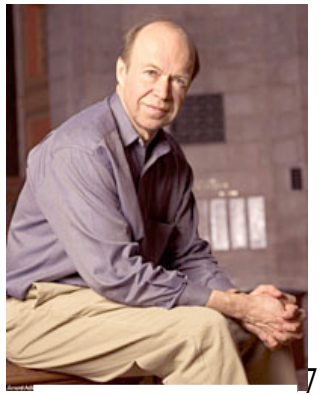
- NASA is the principal source of information about global climate change
  - 14 NASA missions are flying at present
  - 46 instruments are producing an unprecedented flow of data
  - NASA has been a leader in interpreting the causes of climate change
- Goddard has made major contributions to:
  - The definition and implementation of NASA missions
  - The support of the scientific community
  - The creation of climate quality data sets
  - The understanding of the Earth System Science
  - Research based on the use of satellite data

# GSFC Scientists Lead Climate Change Research

The Goddard Institute for Space Studies (GISS) located in New York City, an integrated part of GSFC Earth Science

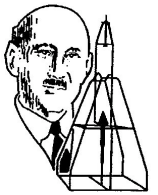


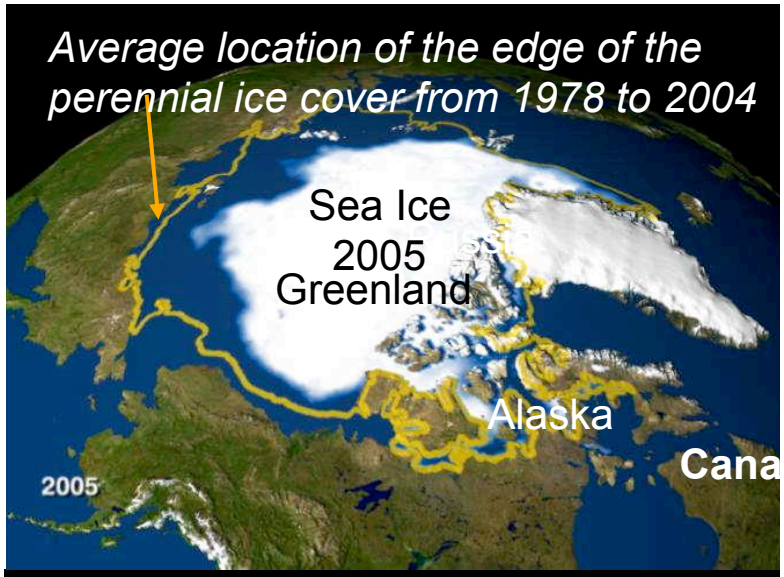

GSFC scientists are observing and modeling climate change caused by human activities, with the biggest driver increasing Carbon Dioxide – which is causing the Earth to warm-up, resulting in the glaciers and polar ice-caps to melt and other effects on the Earths climate



**Dr Jim Hansen**

# The Melting Icecaps

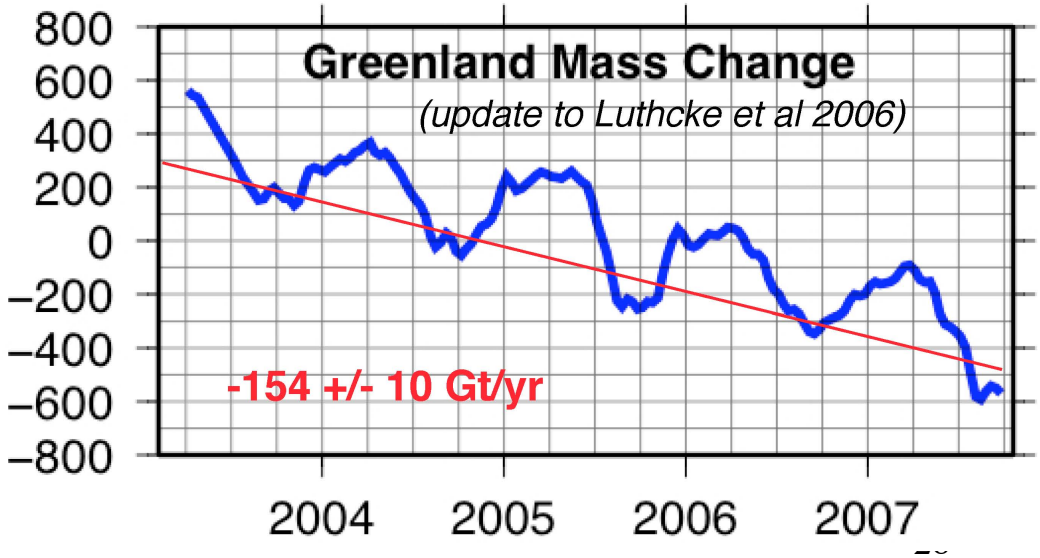






GSFC scientists working with ICESat and GRACE are showing dramatic shrinking at the Greenland ice sheet margins and slight growth in the interior

GRACE – Scott Luthcke

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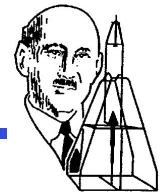
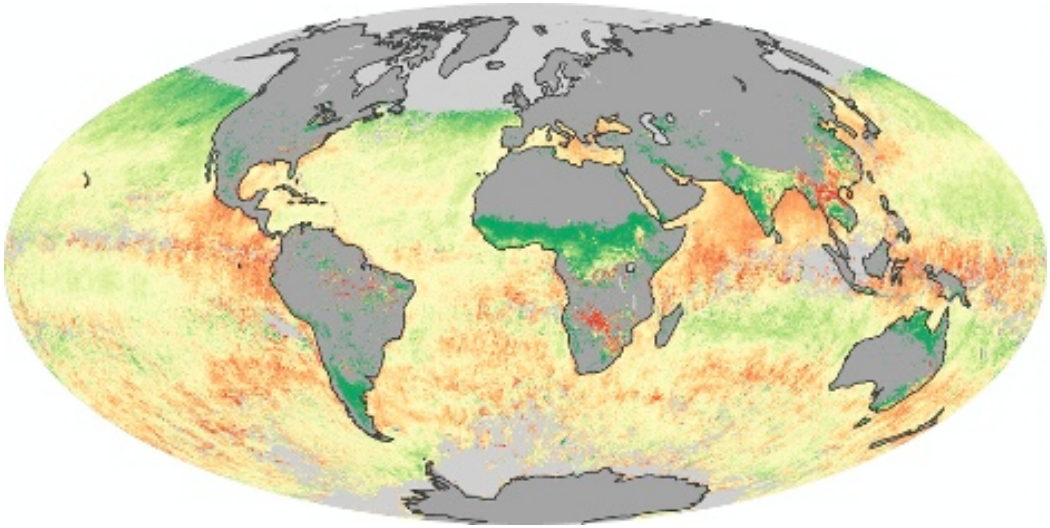
# GLORY - Aerosols Mission



Terra MODIS



Aerosols from burning forests, smoke stacks etc are a large uncertainty in climate change models

Glory will help to quantify the role of aerosols in climate change


L. A. Remer, Y. J. Kaufman, D. Tanré – GSFC, Univ. Lille

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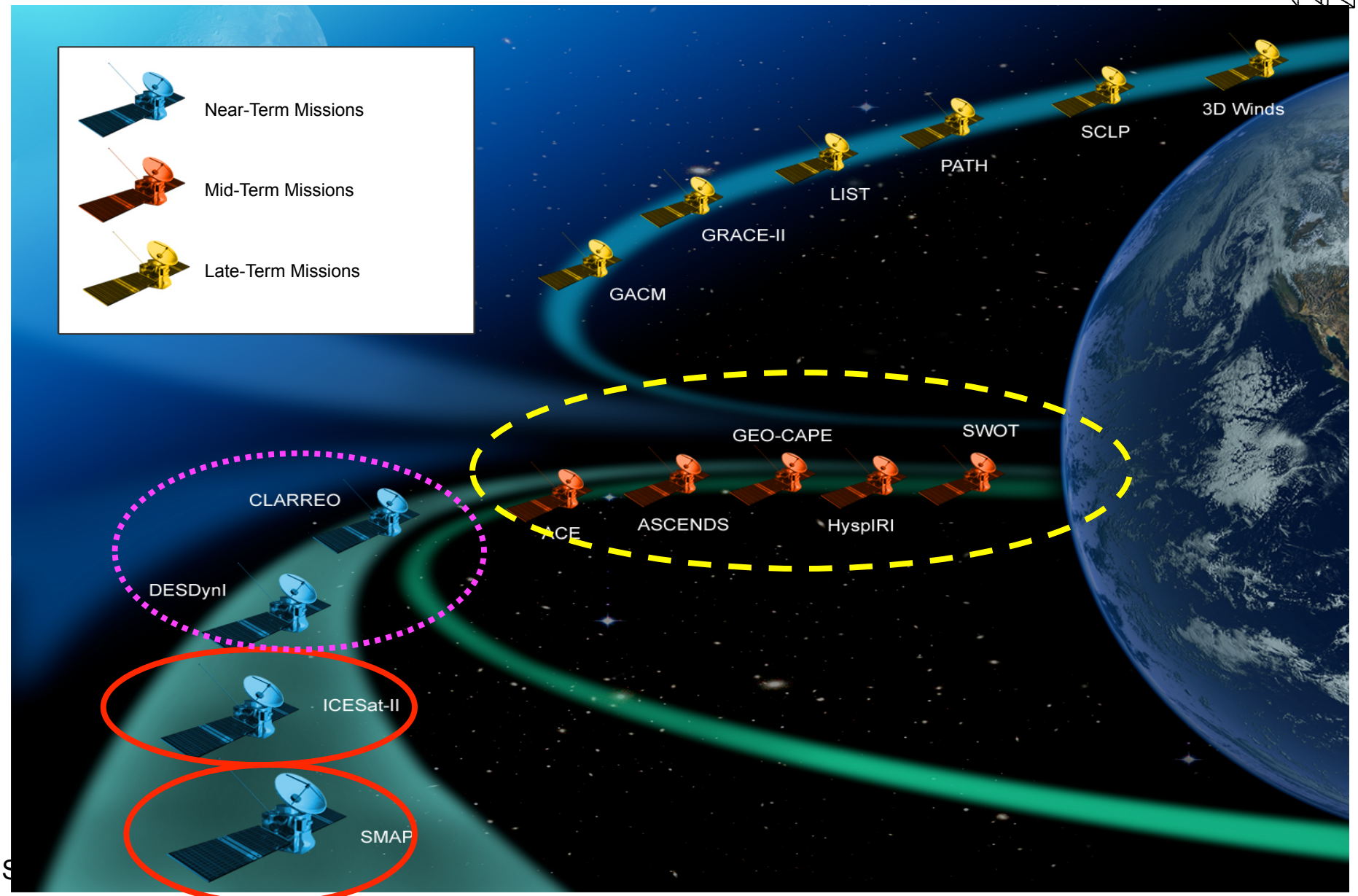
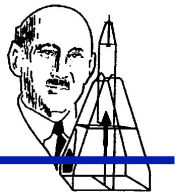
Michael Mischenko
Project Scientist at GISS

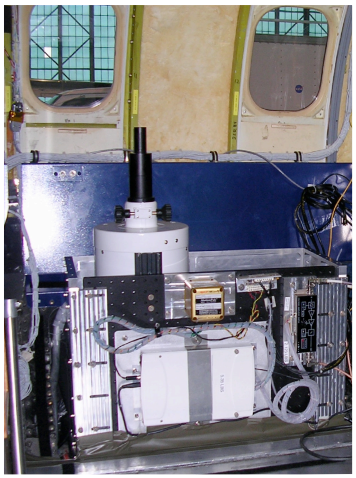
# Earth Science Decadal Survey Missions

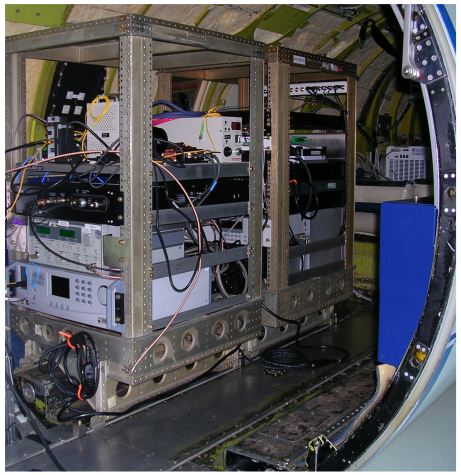


# Airborne Laser Measurements of Atmospheric CO2 to help enable the new Earth Science ASCENDS Mission

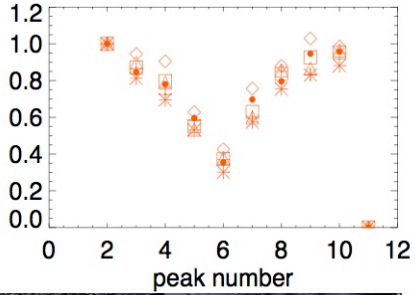
James B. Abshire, Code 690.5

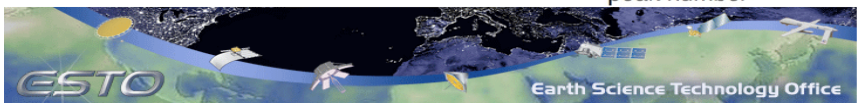


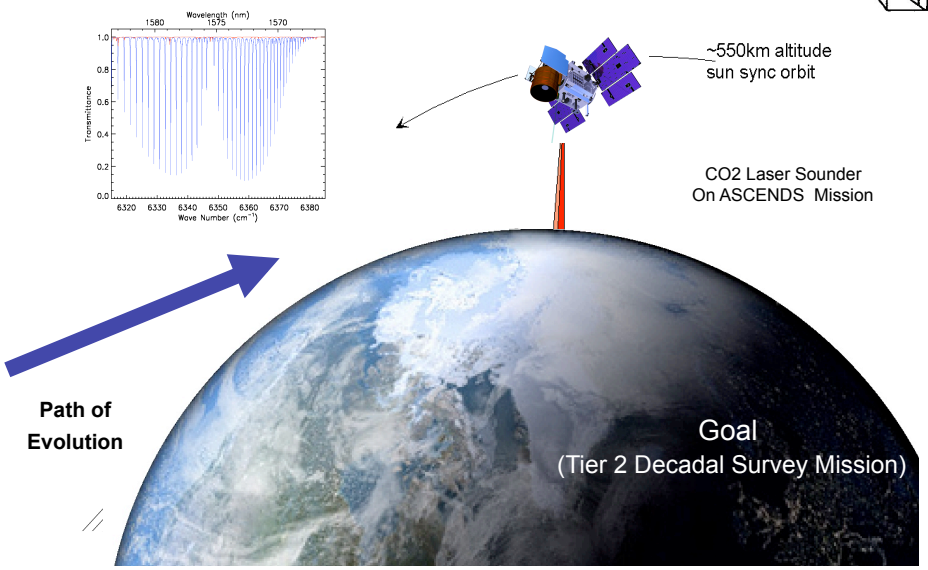





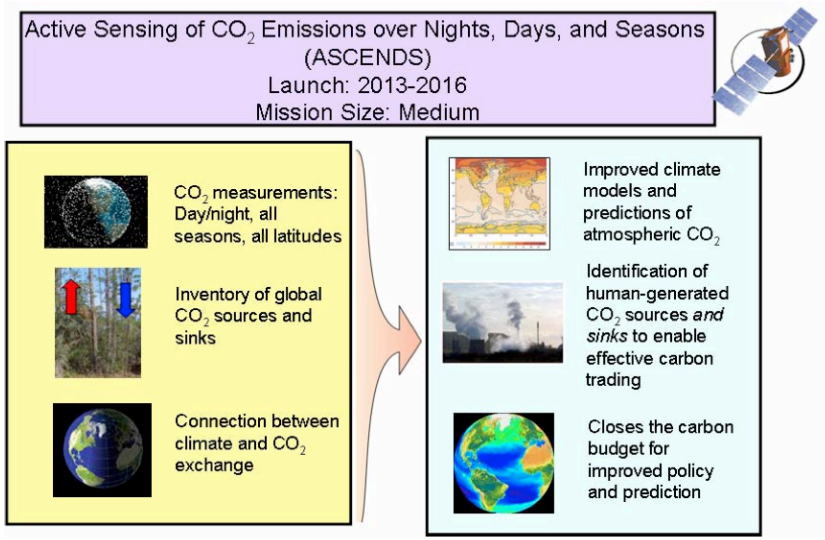
Pulsed laser measurements of a CO2 absorption line in the air column from 10 km altitude to surface



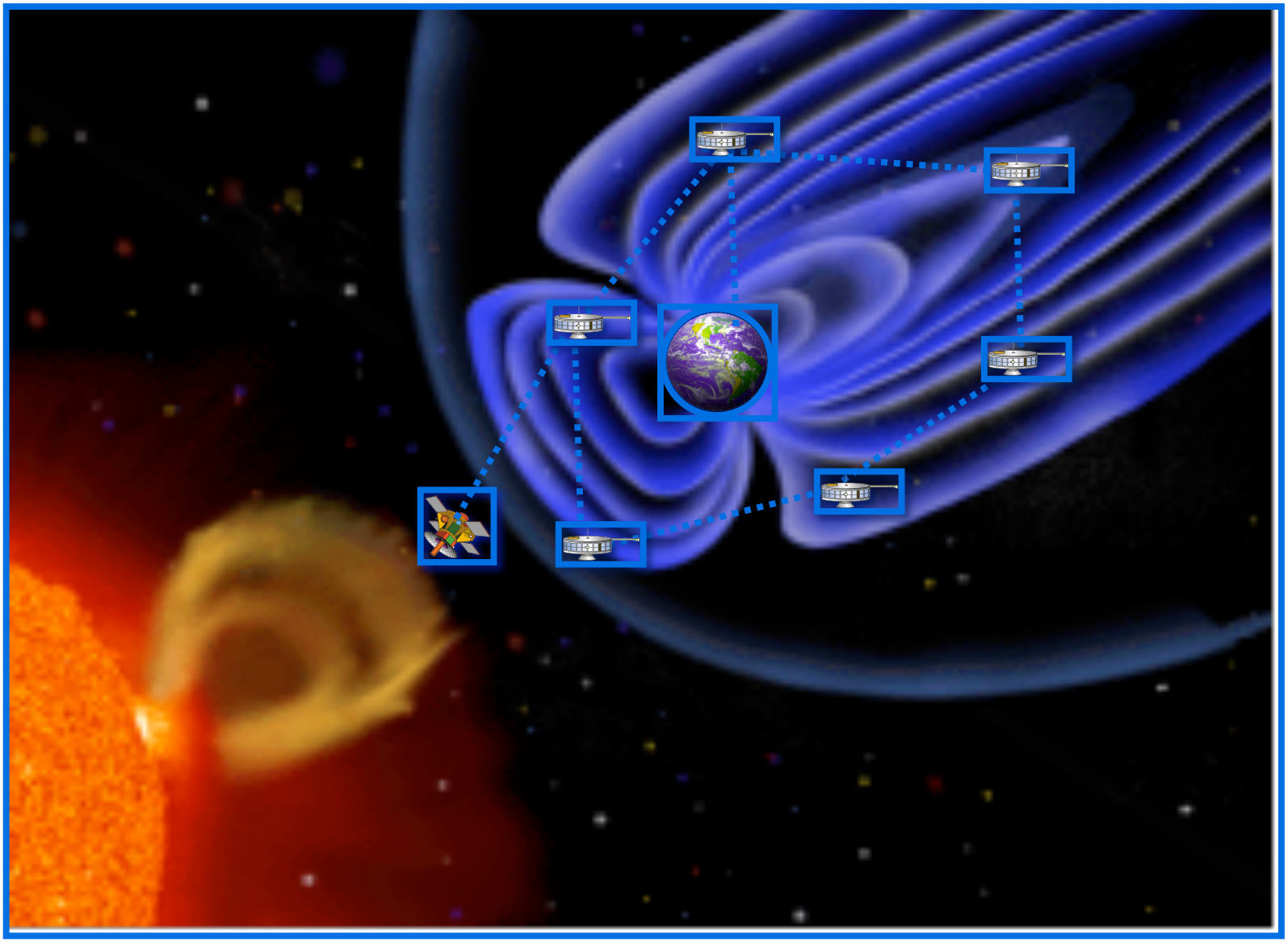




**Active Sensing of $CO_2$ Emissions over Nights, Days, and Seasons (ASCENDS)**



# Heliophysics Division: Living with Our Sun





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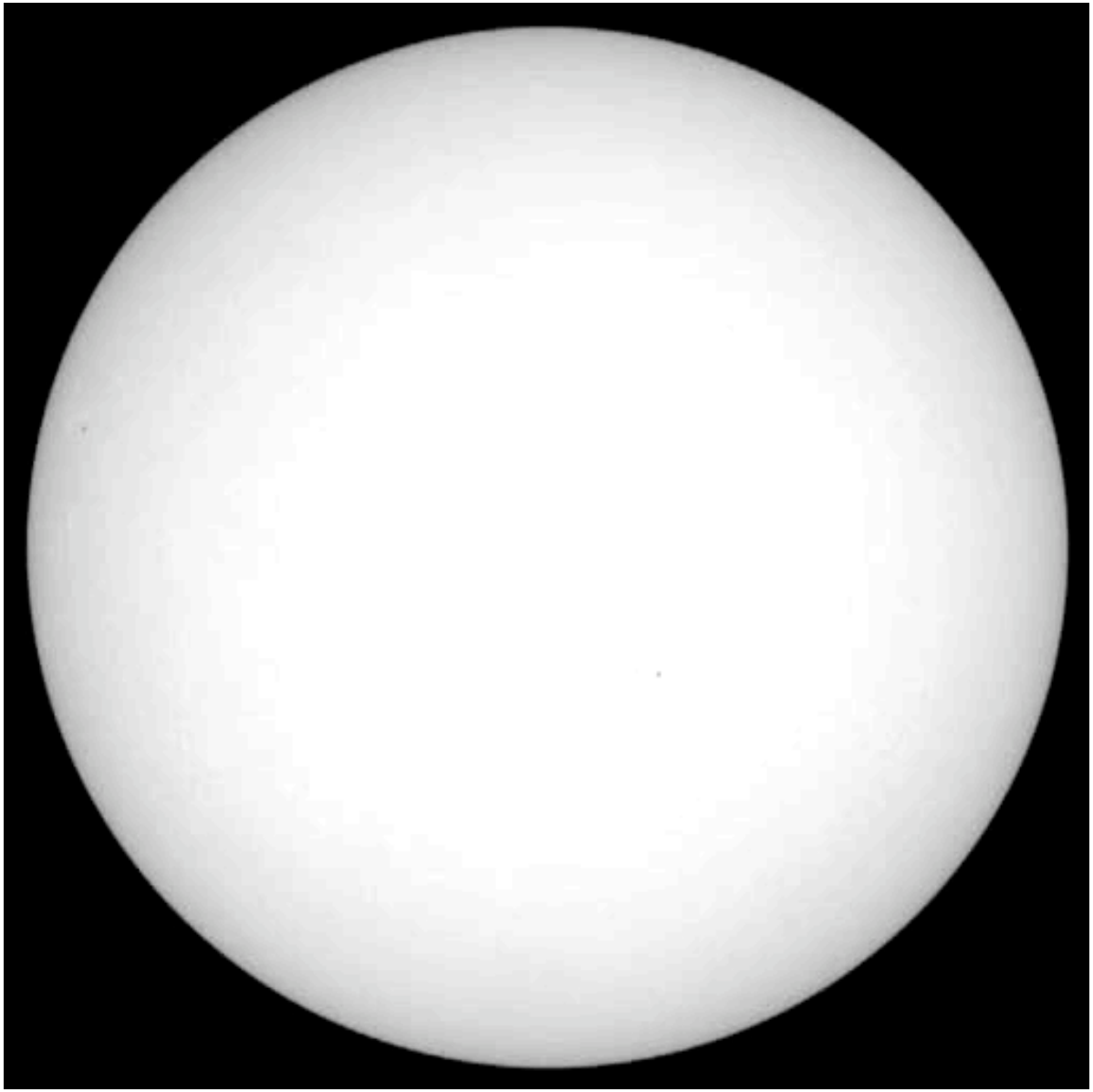
# ESA-NASA Solar and Heliophysics Observatory





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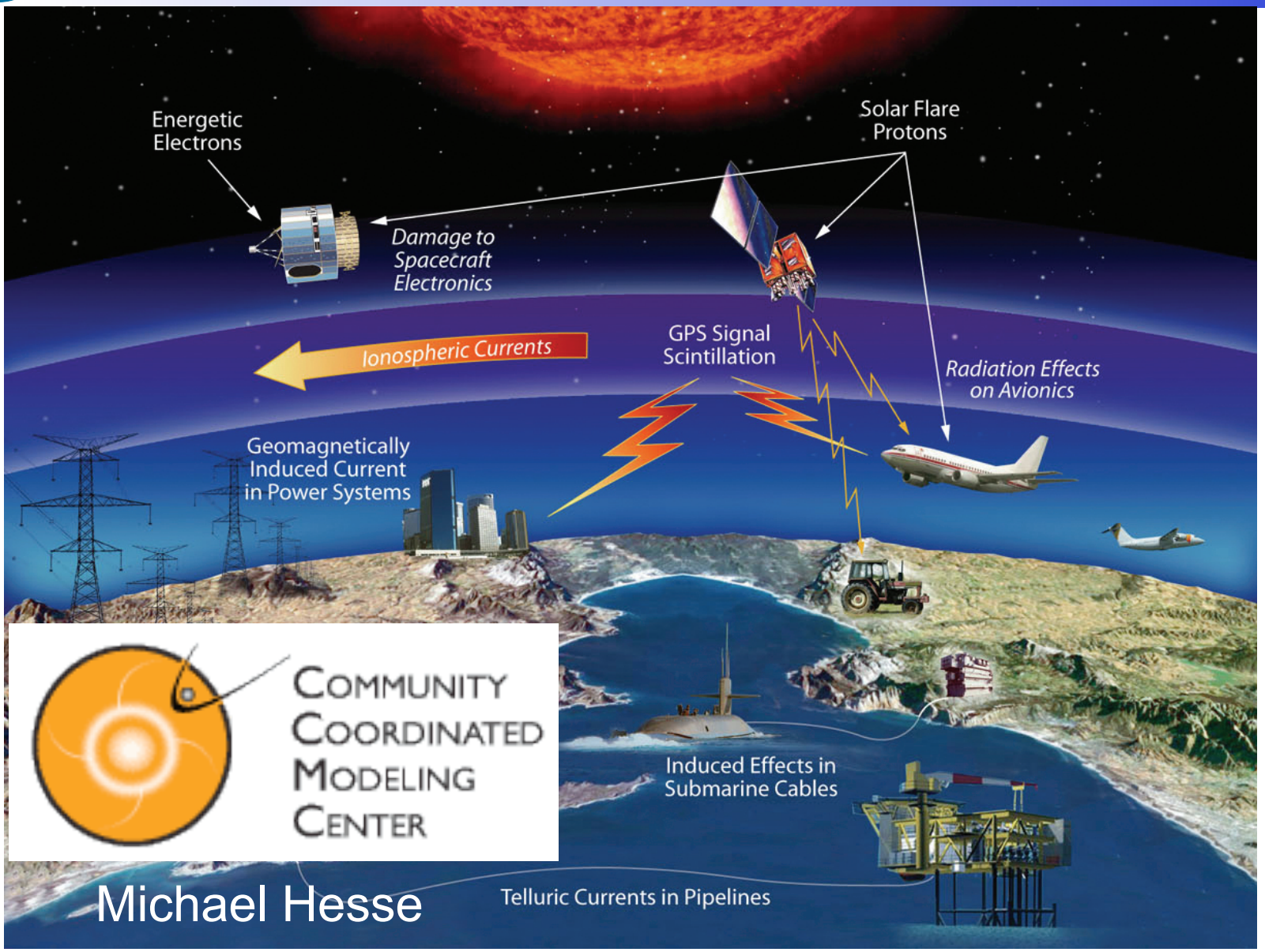
# Space Weather Prediction and its Impact on Society

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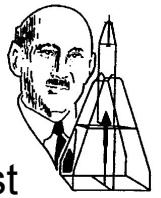
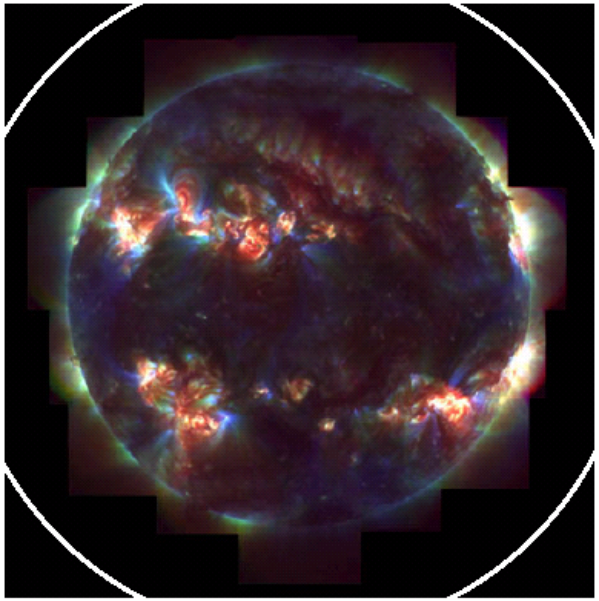
# Solar Dynamics Observatory (SDO)

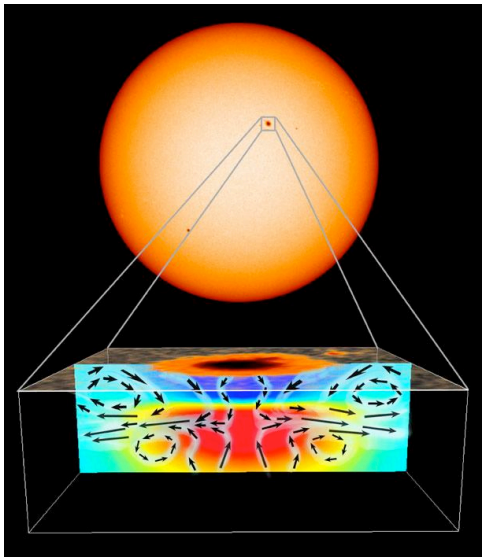


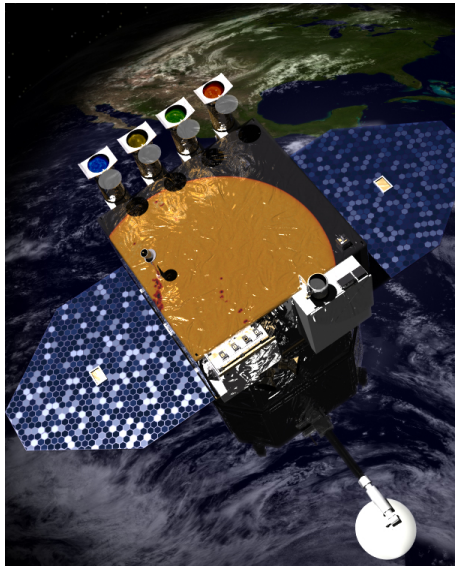


The Solar Dynamics Observatory (SDO) is the first mission to be launched for NASA's Living With a Star (LWS) Program, a program designed to understand the changing Sun and its impacts on Earth

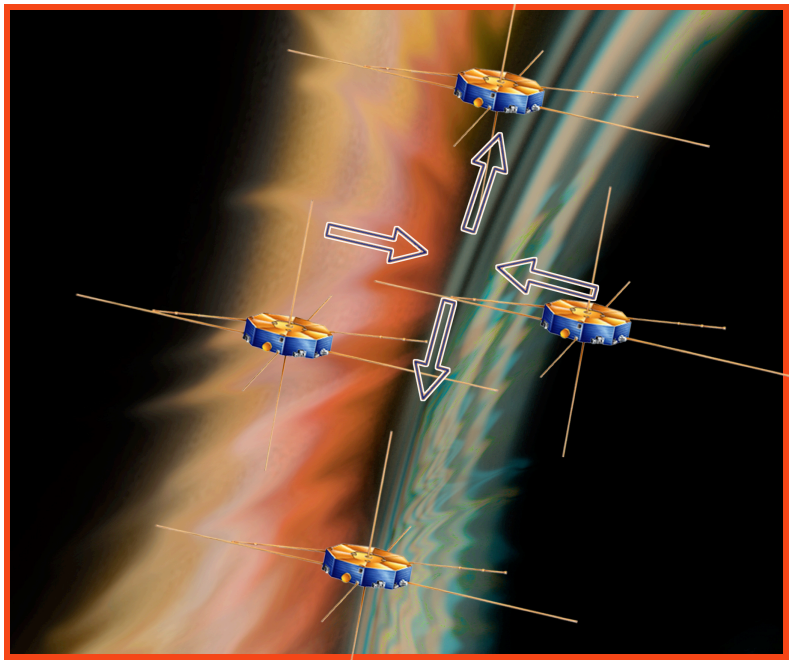
SDO will study the Sun's magnetic field, the interior of the Sun, and changes in solar activity

Spacecraft is being built and integrated at GSFC and is scheduled to be launched in November 2009 into a Geosynchronous orbit with a realtime link to White Sands

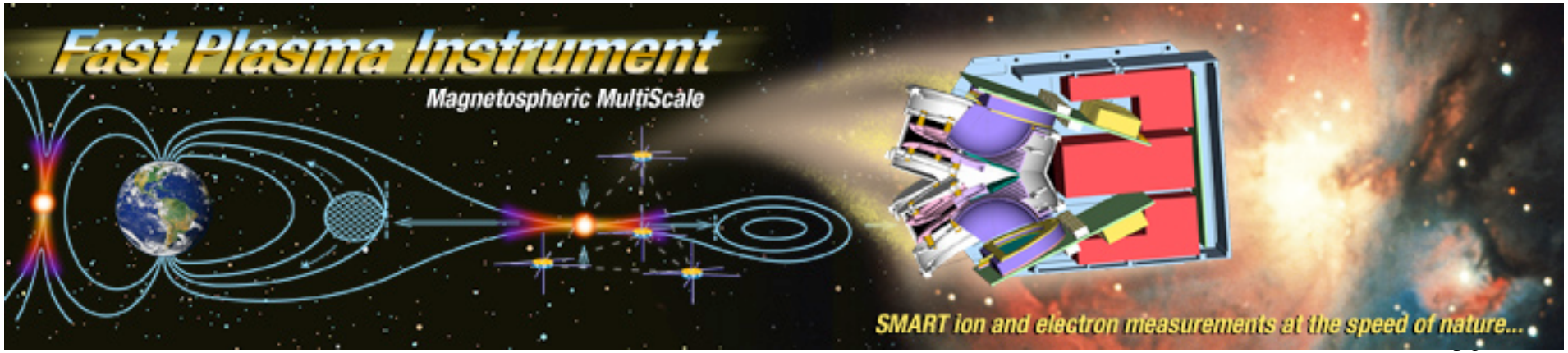




# Magnetospheric Multiscale Mission (MMS)



- Four identical spin stabilized (3 RPM) spacecraft formation launched in 2014 flying in a tetrahedron to measure Electric and magnetic fields, Energetic particles and Hot plasma composition
- Fast Plasma Investigation from GSFC led by Tom Moore

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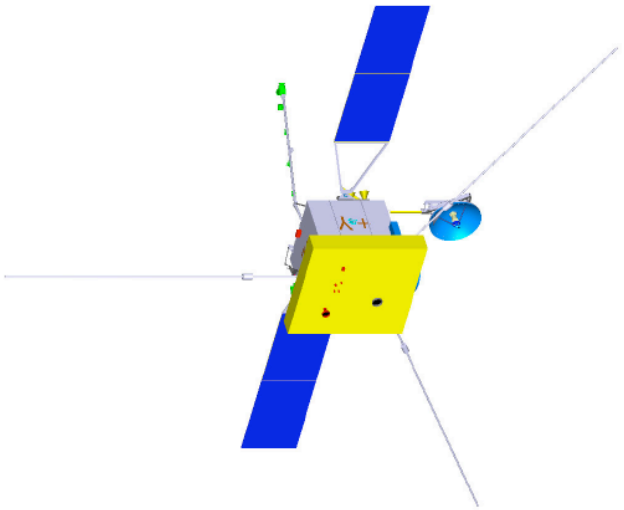
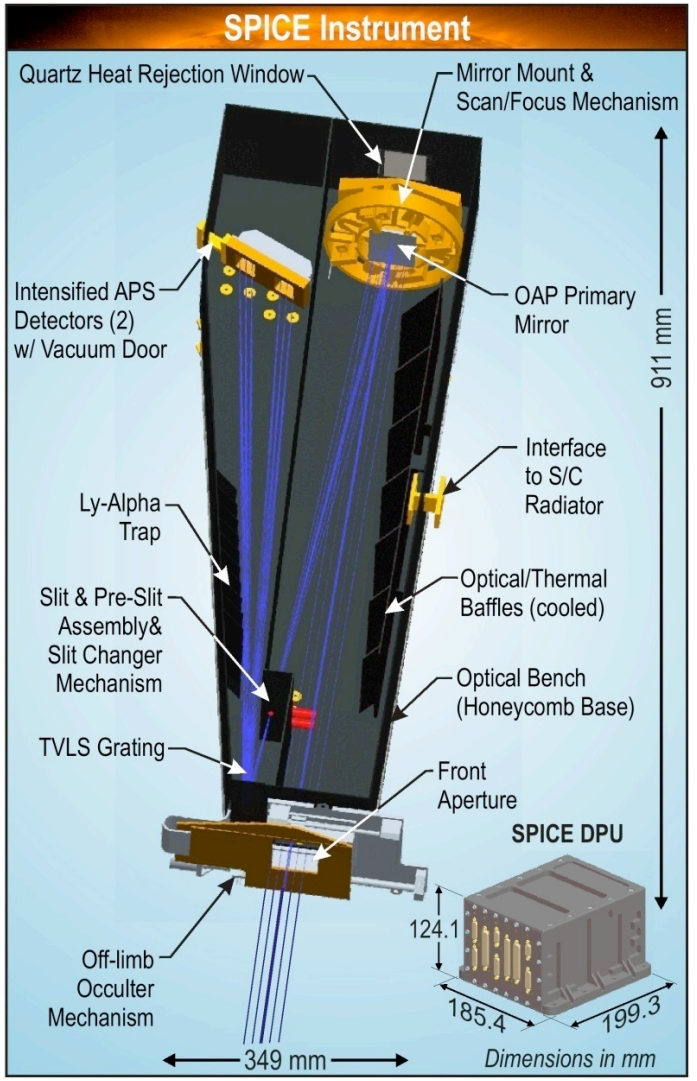
# SPICE – Solar Orbiter Instrument

- Don Hassler, SwRI, and Joe Davila, GSFC
- SPICE is an *Imaging Coronal Spectrograph*
- Movable Occulter to observe both on the solar disk and out to >3.0 Rs
- Unique capability to *remotely characterize plasma properties* of regions near the Sun to compare with *in-situ* measurements from ESA's Solar Orbiter



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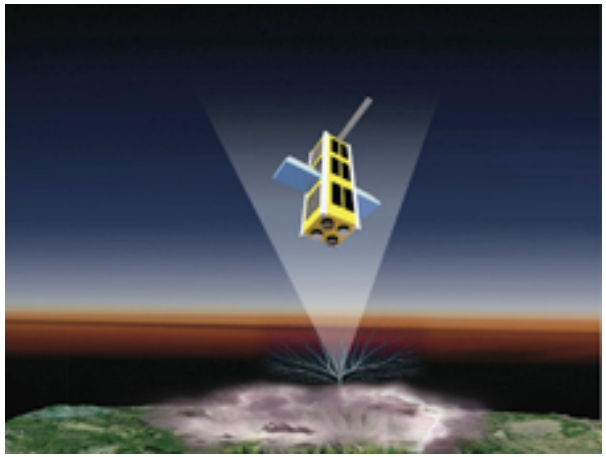
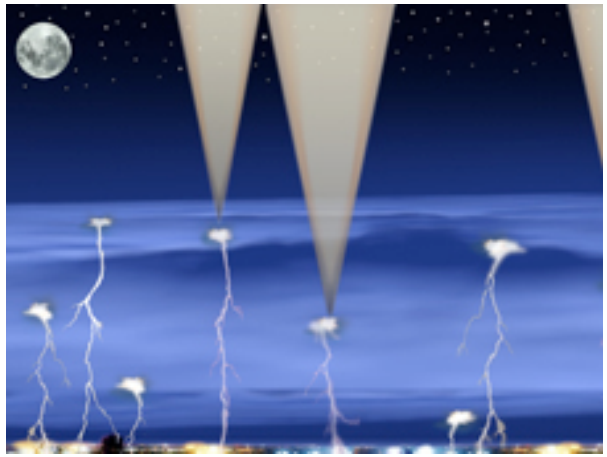
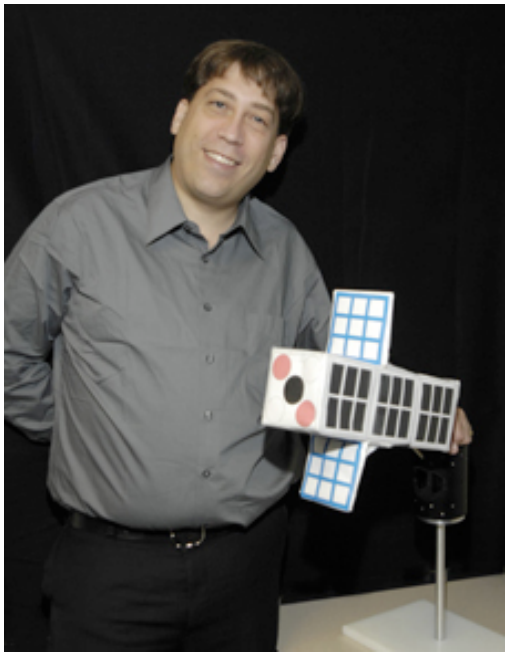
# NSF / NASA 'Firefly' CubeSat Selected

Firefly will Study Link Between Lightning and Terrestrial Gamma Ray Flashes



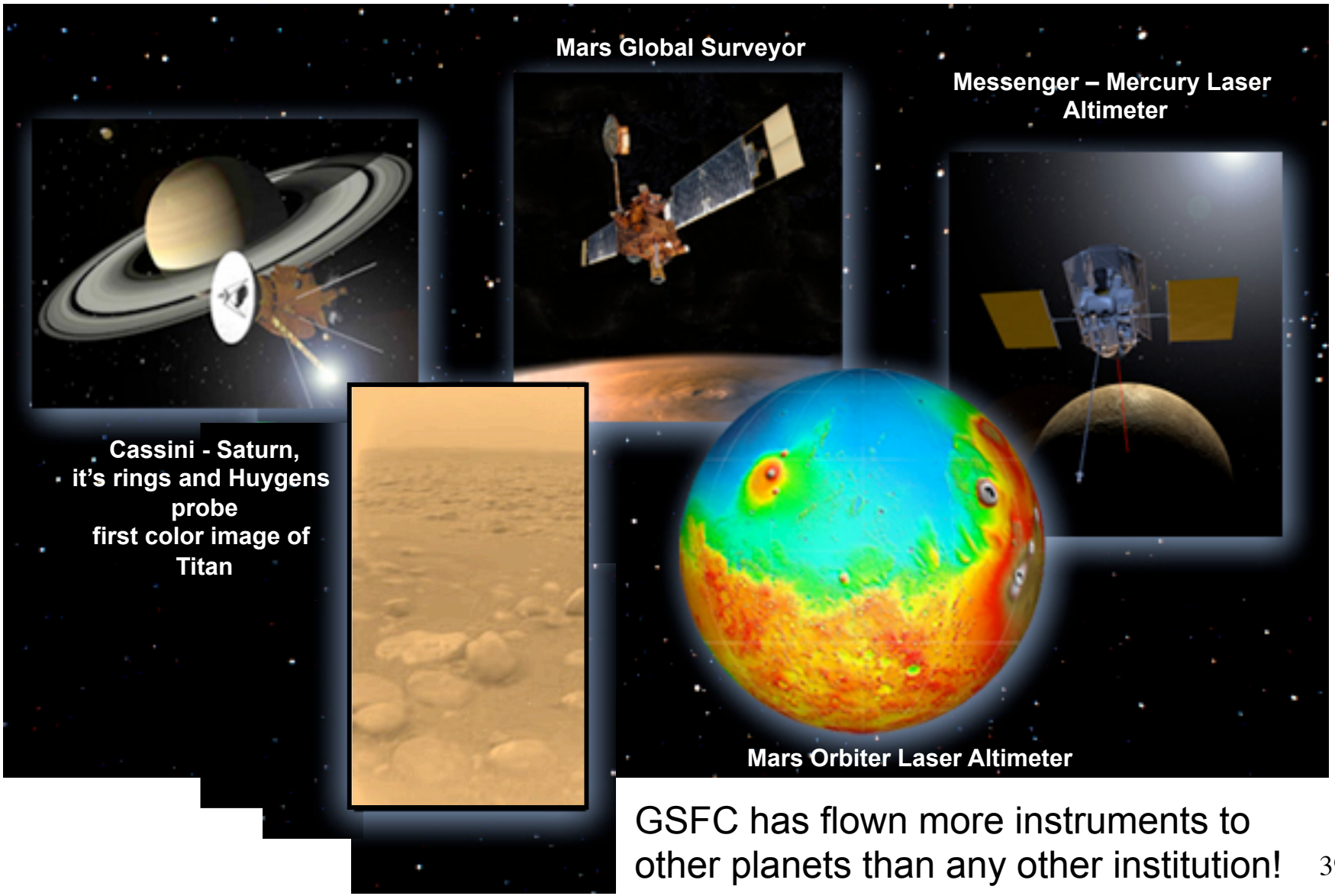




Doug Rowland
(Heliophysics)

Joe Hill
(Astrophysics)

# Solar System Exploration




GSFC has flown more instruments to other planets than any other institution!



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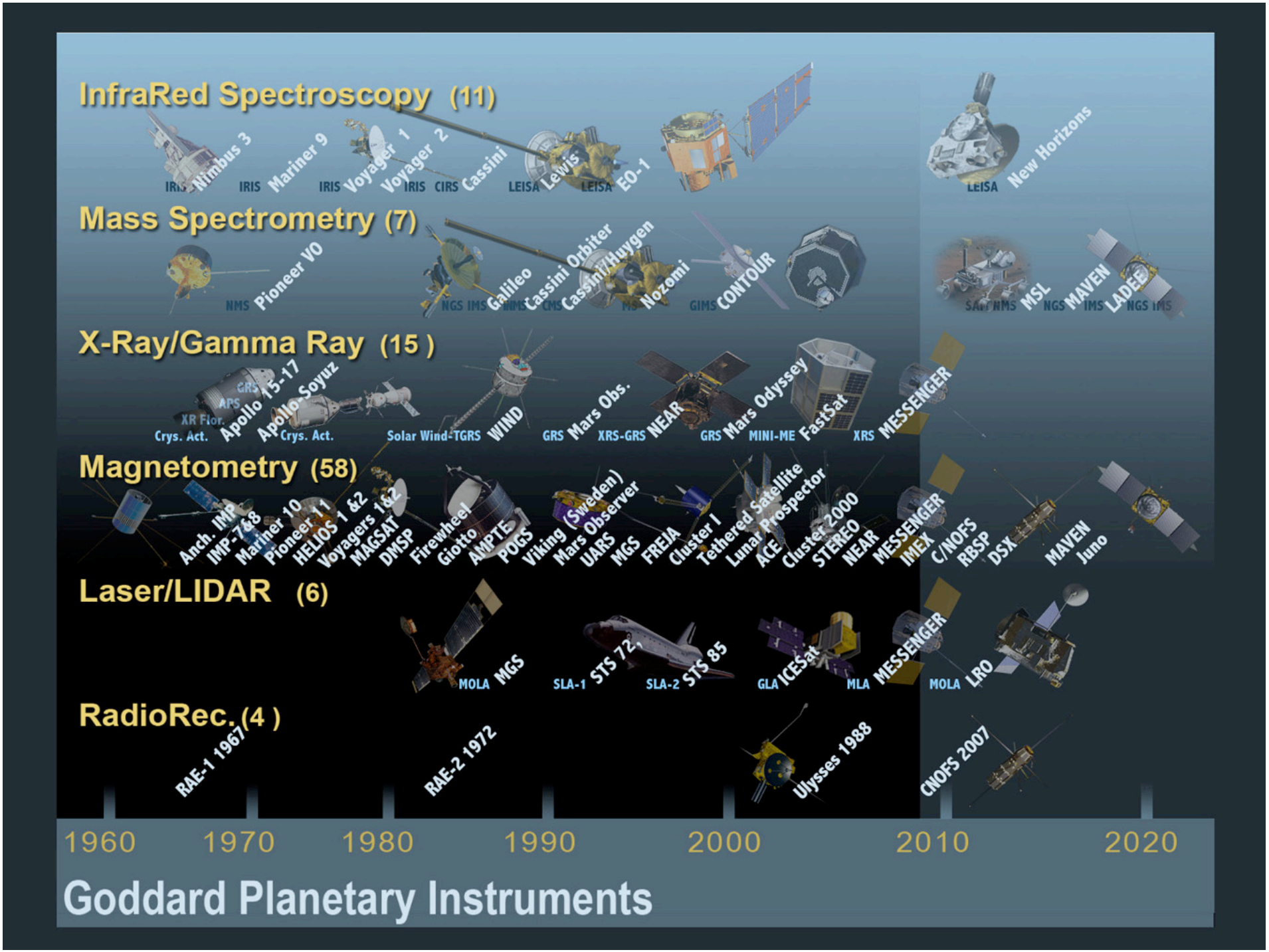

InfraRed Spectroscopy (11)
IRIS Nimbus 3
IRIS Mariner 9
IRIS Voyager 1
Voyager 2
IRIS CIRS Cassini
LEISA Lewis
LEISA EO-1
LEISA New Horizons
Mass Spectrometry (7)
NMS Pioneer VO
NGS IMS Galileo
Cassini Orbiter
Cassini/Huygen
Nozomi
GIMS CONTOUR
SAM NMS MSL
NGS MAVEN
IMS LADEE
NGS IMS
X-Ray/Gamma Ray (15 )
GRS
APS
XR Flor.
Crys. Act.
Apollo 15-17
Apollo-Soyuz
Crys. Act.
Solar Wind-TGRS
WIND
GRS Mars Obs.
XRS-GRS NEAR
GRS Mars Odyssey
MINI-ME FastSat
XRS MESSENGER
Magnetometry (58)
Anch. IMP
IMP-7&8
Mariner 10
Pioneer 11
HELIOS 1 &2
Voyagers 1&2
MAGSAT
DMSP
Firewheel
Giotto
AMPTE
POGS
Viking (Sweden)
Mars Observer
UARS
MGS
FREJA
Cluster I
Tethered Satellite
Lunar Prospector
ACE
Cluster 2000
STEREO
NEAR
MESSENGER
IMEX
C/NOFS
RBSP
DSX
MAVEN
Juno
Laser/LIDAR (6)
MOLA MGS
SLA-1 STS 72
SLA-2 STS 85
GLA ICESat
MLA MESSENGER
MOLA LRO
RadioRec. (4 )
RAE-1 1967
RAE-2 1972
Ulysses 1988
CNOFS 2007
1960
1970
1980
1990
2000
2010
2020
Goddard Planetary Instruments

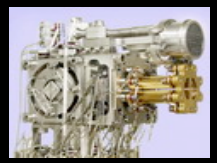
# MAVEN

## *Mars Atmosphere and Volatile EvolutioN (MAVEN) Mission*

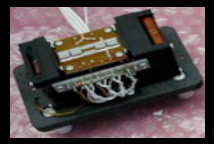
*Bruce Jakosky, Principal Investigator*
*Bob Lin, Deputy PI*
*David F. Mitchell, Project Manager*
*Joe Grebowsky (695) is the Project Scientist*

*NGIMS (Neutral Gas and Ion Mass Spectrometer – Paul Mahaffy (699)*
*MAG (Magnetometer) - Mario Acuna (695)*
Science Cols - Jack Connerney (695), Wayne Kasprzak (699)

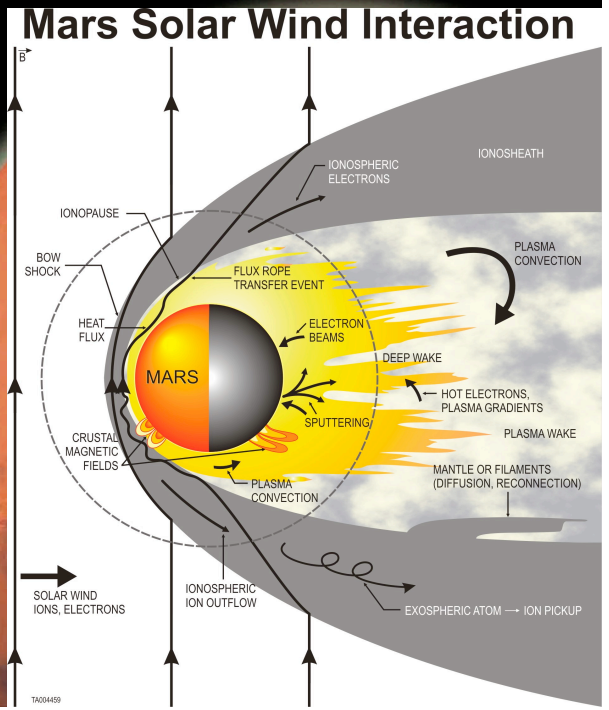
***Loss from the upper atmosphere to space is key to determining the history of the atmosphere, climate, and water, and thereby understanding Martian habitability.***



**NGIMS**

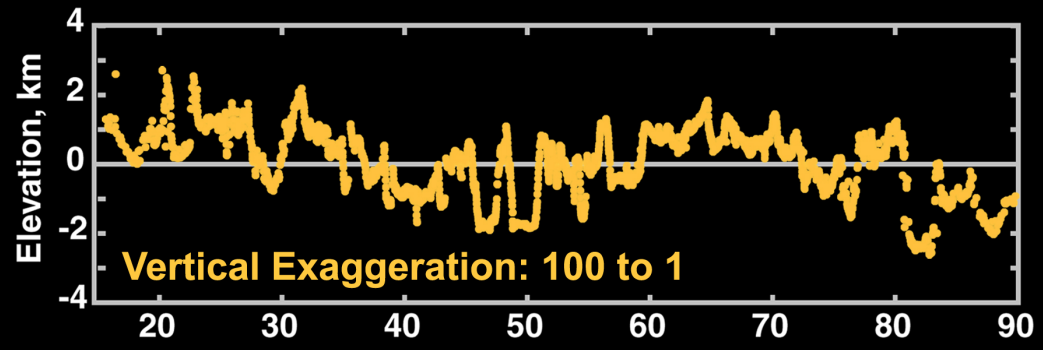


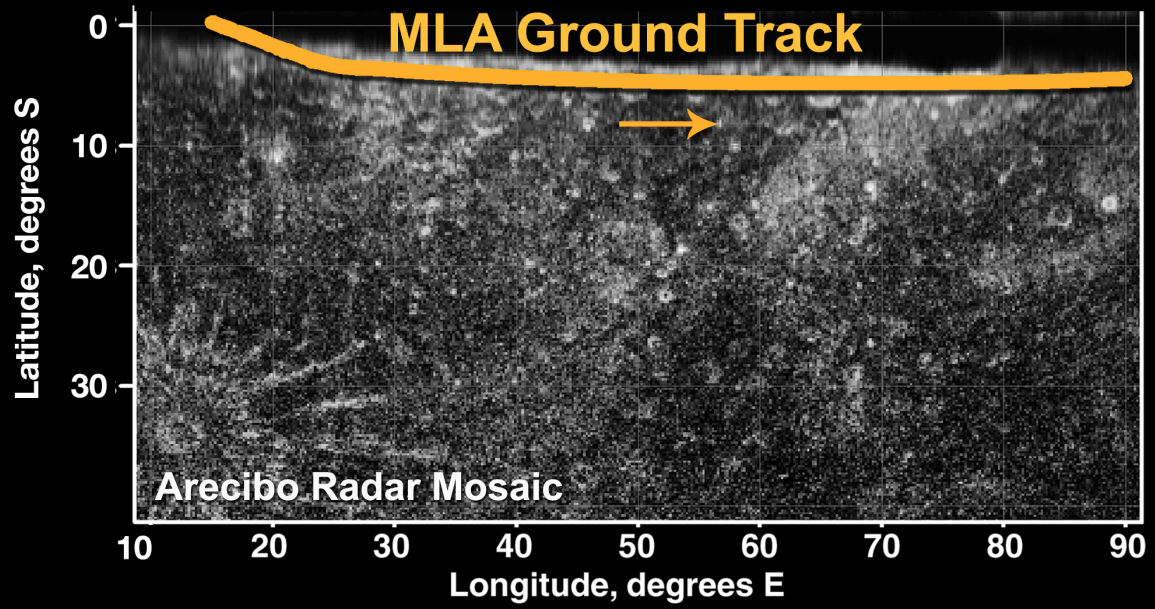
**MAG**



# Mercury Laser Altimeter Profile

**Mercury Laser Altimeter (MLA)**



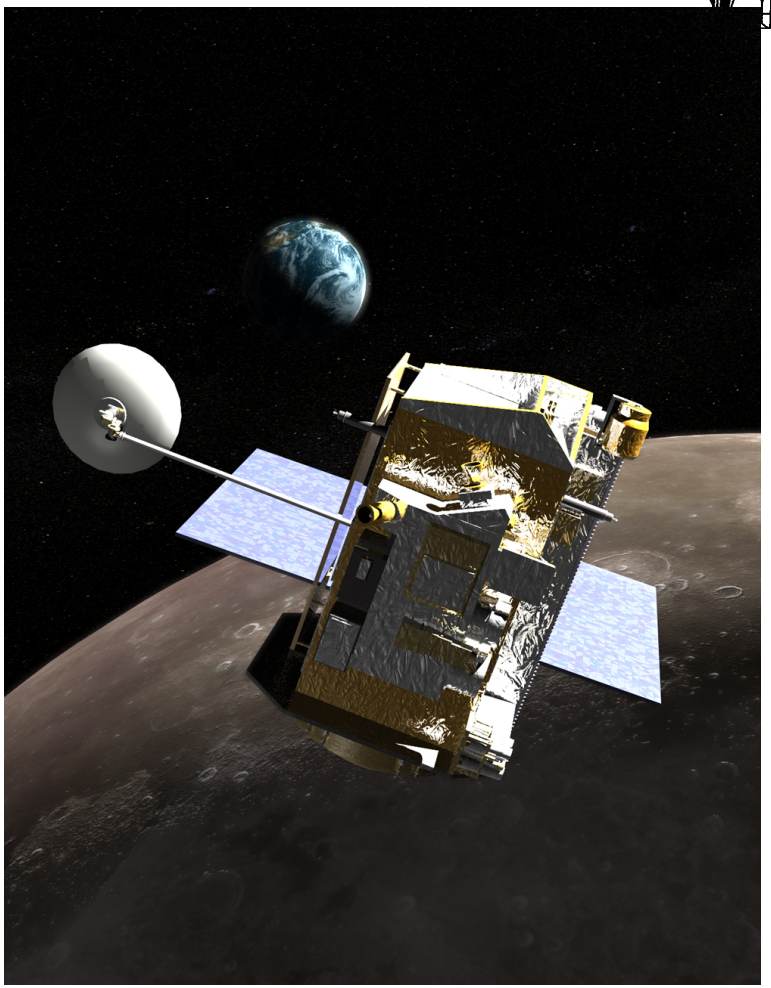

Dave Smith (GSFC), Maria Zuber (MIT), et al

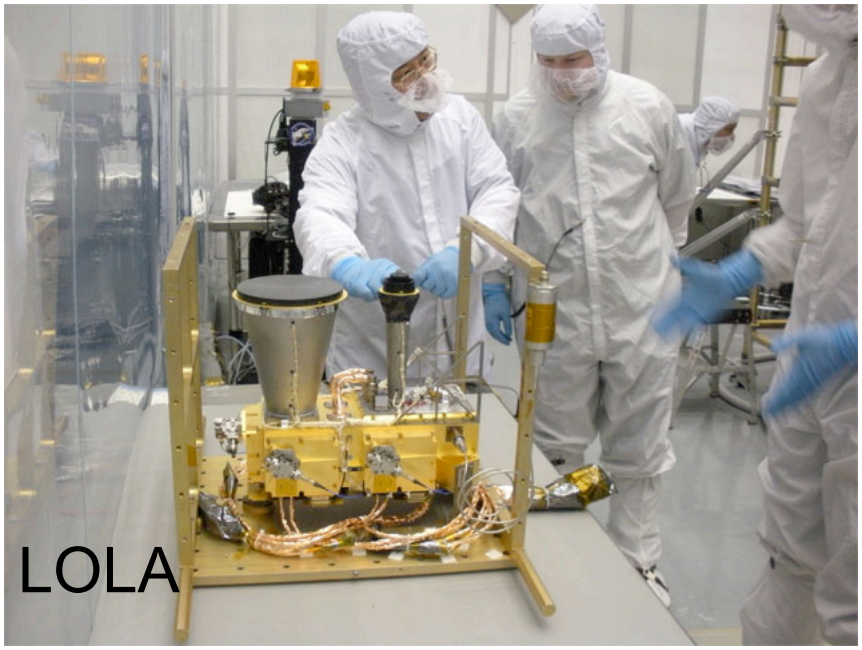
SED: Excellence, Stewardship, Vision

# Lunar Topography: The LRO Laser Altimeter

The LRO Mission objective is to conduct investigations to prepare for and support future human exploration of the Moon.

GSFC is providing a laser altimeter (LOLA) that will provide detailed maps of the Moon's topography **– *PI Dave Smith***






**1 year mission in a 50 km lunar polar orbit**



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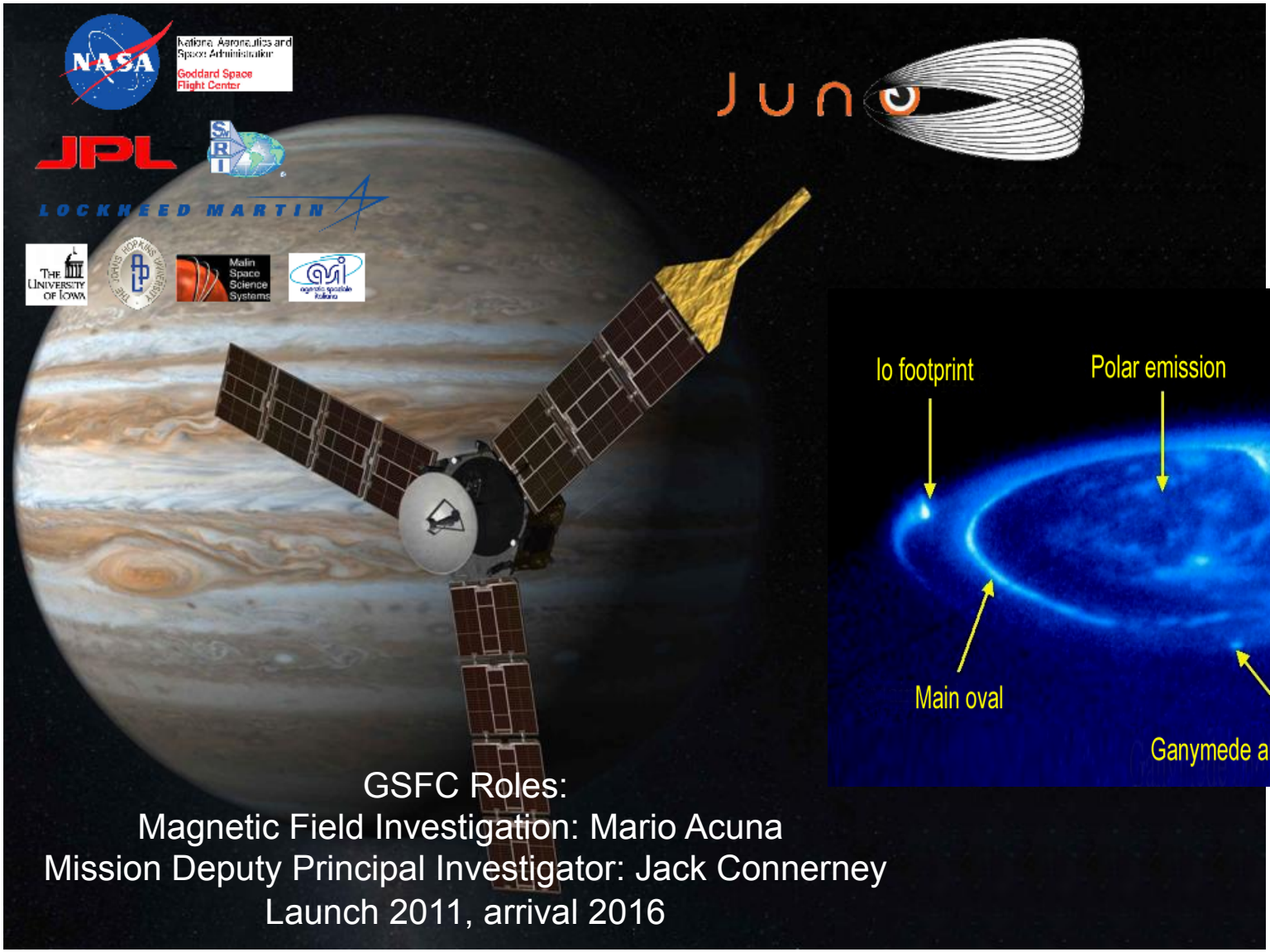
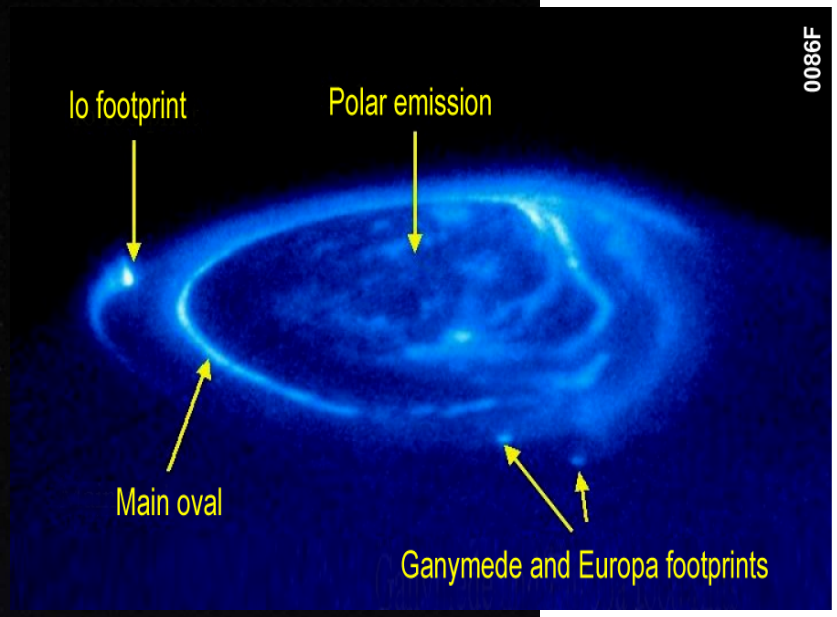
# GSFC goes to Jupiter



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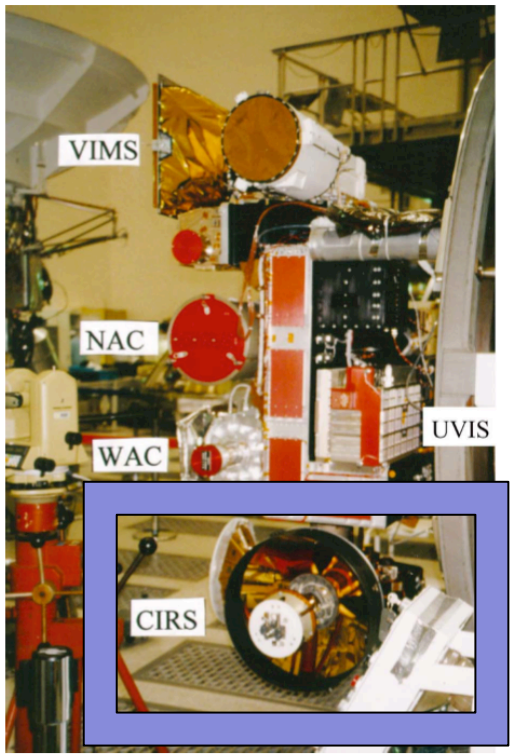
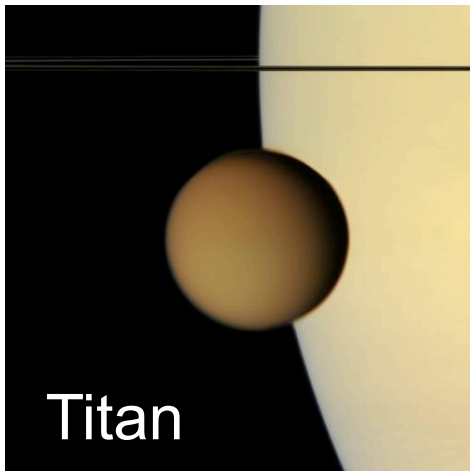
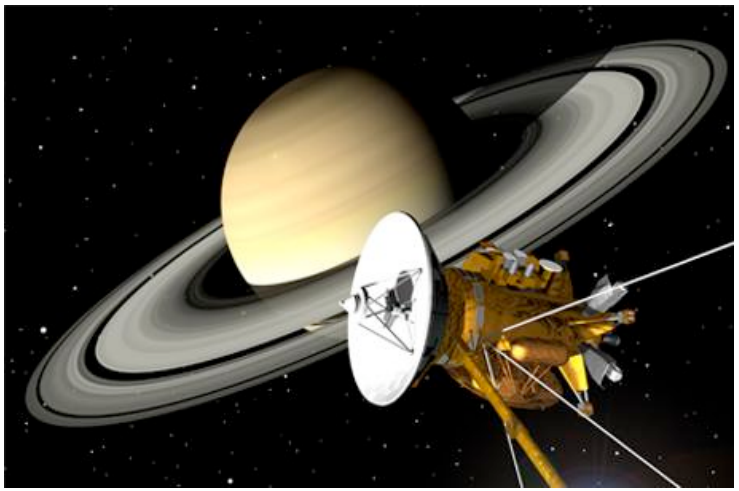
# GSFC at Saturn: the CIRS Instrument

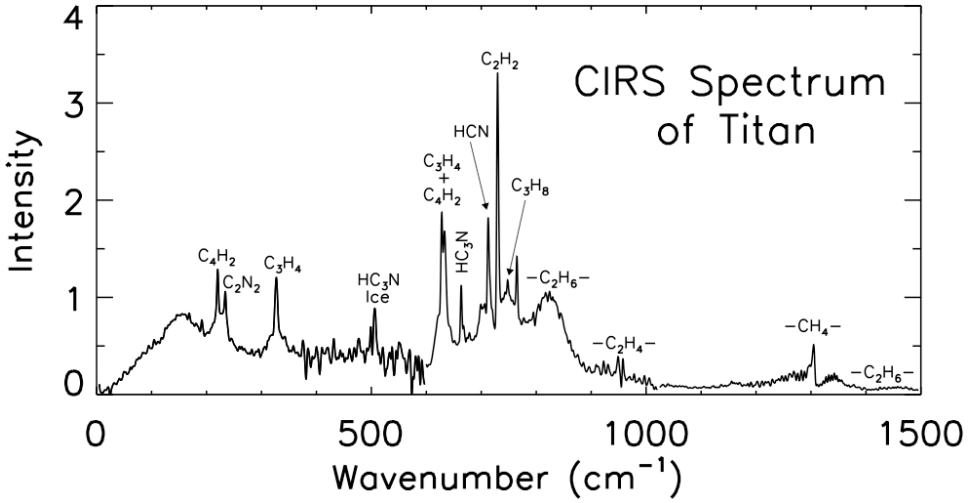
GSFC Composite Infrared Spectrometer (**CIRS**) on board the *Cassini* Spacecraft orbiting the Saturn System



GSFC




Identifications of hydrocarbon and nitrile gases (e.g. Cyanide) in the atmosphere of Saturn's moon Titan

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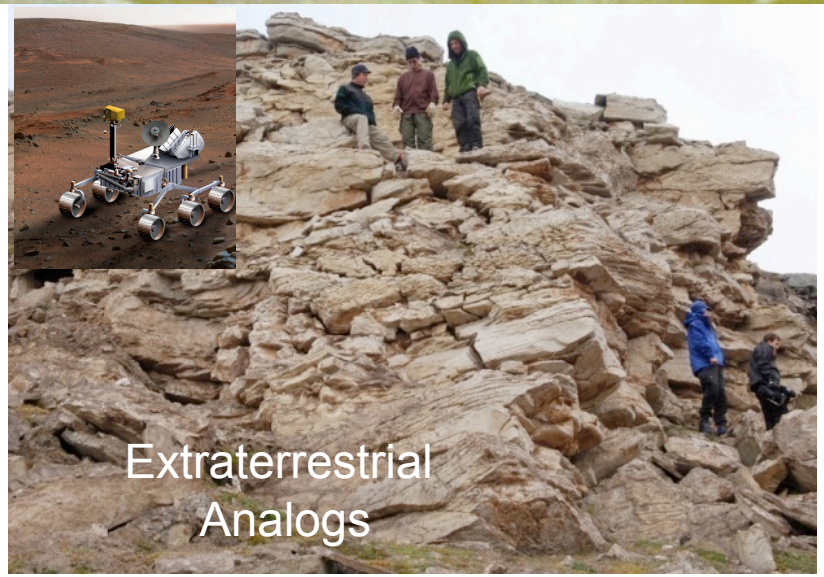
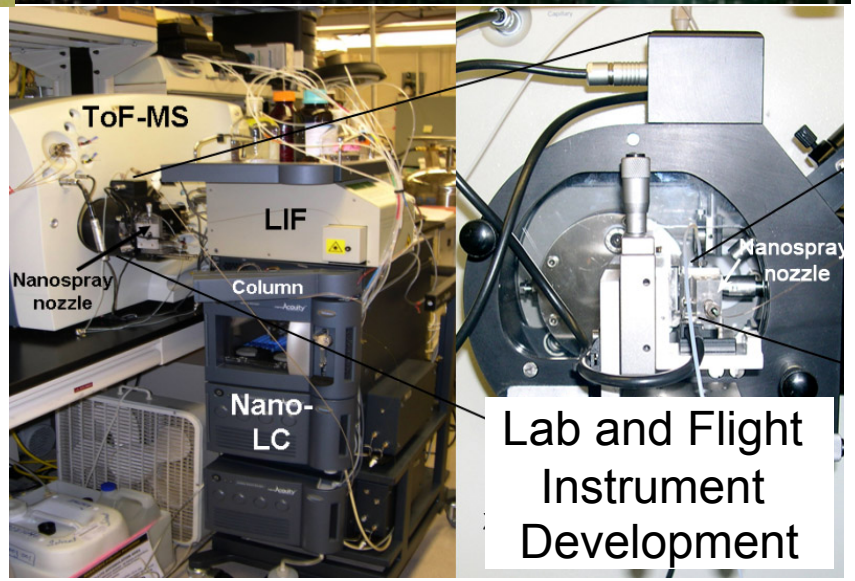
# Search for the Building Blocks of Life





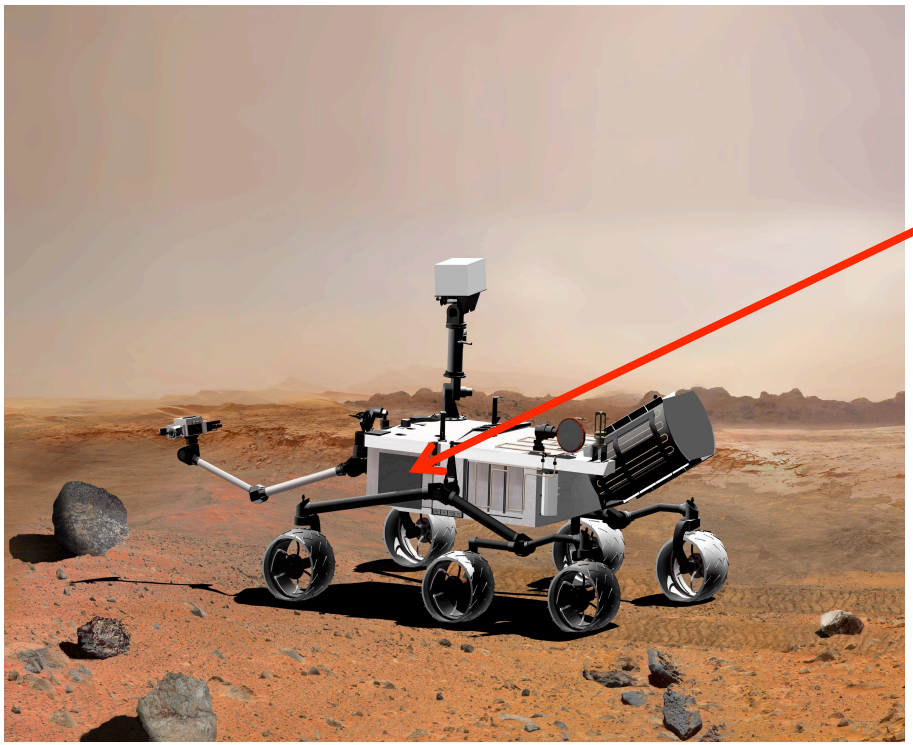

SED: Excellence, Stewardship, Vision

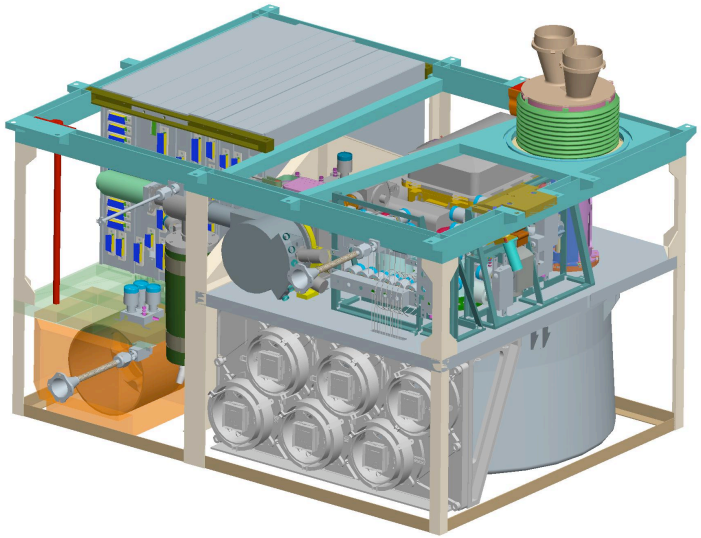
Dworkin, Eigenbrode, Glavin, Elsila, Martin, and Stern

# Mars Science Laboratory

Sample Analysis at Mars (SAM)
Paul Mahaffy (GSFC) - P.I.

SAM is a suite of instruments on the next Mars rover that will reveal the potential for life on Mars





**Mars Science Laboratory will be launched in 2011 and arrive on Mars in 2011**

SAM science goals

- Search for organic compounds of biotic and prebiotic relevance
- Study habitability of Mars by measuring oxidants
- Investigate atmosphere and climate evolution

# Examples of SED Scientist Recognition

Dr Neil Gehrels Inducted into American Academy of Arts and Sciences 2008

Dr John Mather 2006 Nobel Prize

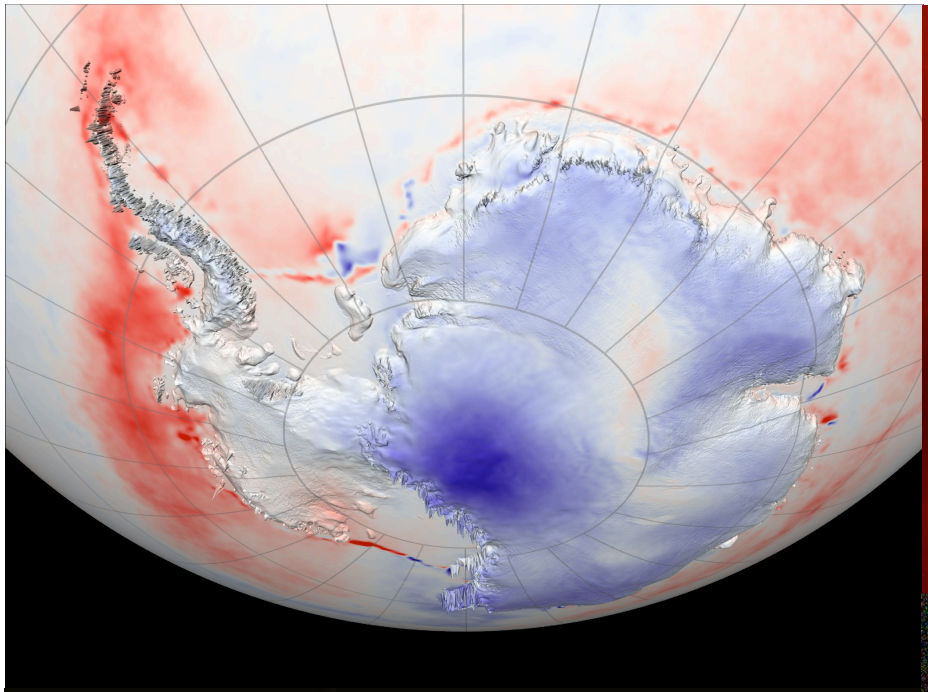
National Academy of Sciences awards the 2008 Arctowski Medal to Dr. Leonard Burlaga

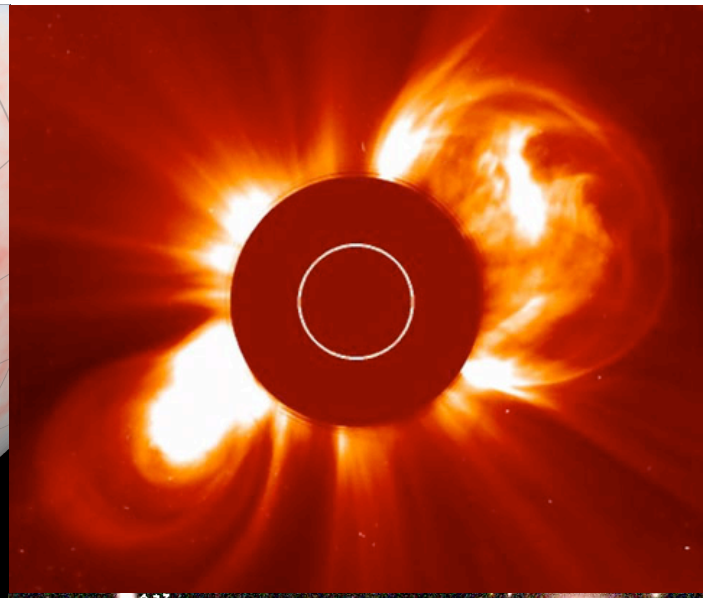
Dr Christa Peters-Lidard 2007 Arthur S. Flemming Award

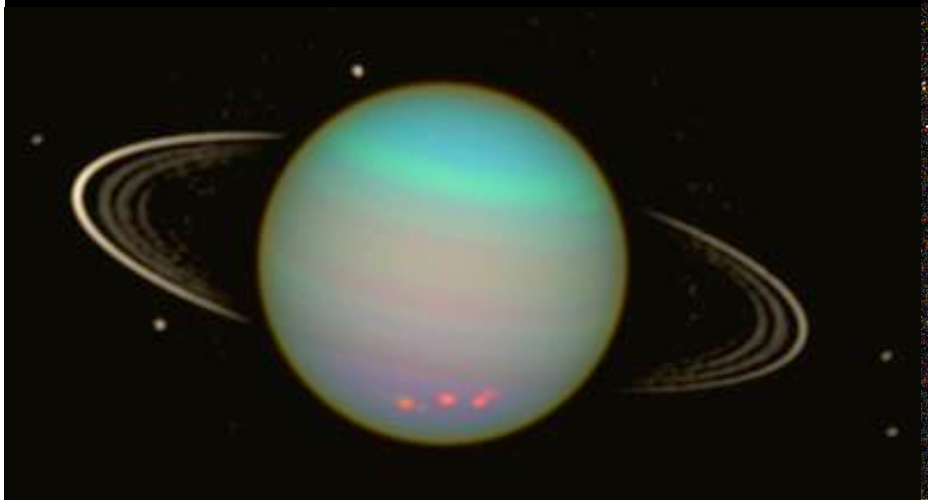
Dr Mario Acuna 2007 elected to National Academy of Sciences

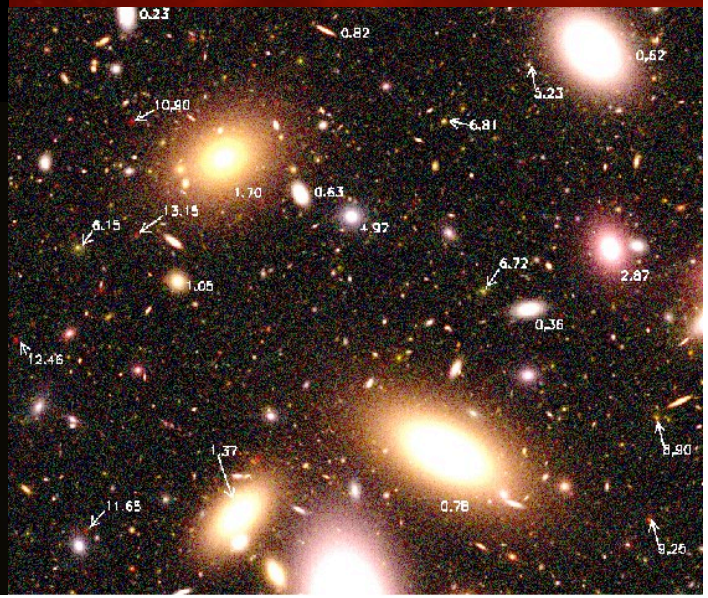
Dr Claire Parkinson elected to the National Academy of Engineering in 2009

# GSFC at the Frontiers of Earth and Space Science












SED: Excellence, Stewardship, Vision